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An Illustrated Weekly Journal

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182 No.4721 LONDON, FRIDAY, AUGUST 31, 1956 PRICE 2s.

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Remoteness
Automatic selection of slave unit
Manual selection of slave unit
Automatic sequence of operations
Automatic activation of system
Hydraulic power actuation
Hydraulic power actuation under mechanical controller
Manual hydraulic standby
SEQUENCE CONTROL AT FORD WORKS
In this installation at Ford Works, Dagenham, four shale bins are automatically emptied in sequence.
The emptying time is controllable, so is the period between successive performances, and a sequence valve ensures that the inlet gate is shut during emptying before the outlet door opens.
After emptying, the inlet gate is not opened until the outlet has been closed. Electronic timers control the periods and trigger the thrustor-operated valves which govern the actuation of the gate-opening cylinders.
Further, as soon as emptying begins, a Redler conveyor is set in motion to carry away the shale, and is left running long enough to carry away the whole of the batch of shale.
LOCKHEED HYDRAULIC BRAKE COMPANY LIMITED, SHAW ROAD, SPEKE, LIVERPOOL 19
Lockheed
REGD TRADE MARK
INDUSTRIAL HYDRAULICS

ENGINEERING

An Illustrated Weekly Journal

Vol. 182 No. 4721 AUGUST 31, 1956

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THE SUN NEVER SETS

MOST men are, at heart, adventurers and explorers. Given the right influences and contacts during their youth they might have left hearth and home, setting out for some distant colony or unknown territory. But most men pass through their 'teens and twenties without encountering anyone or anything adventurous which is sufficiently powerful to overcome their youthful uncertainties. The prizes seem to go to those who plan their careers; to those who spend their first years after school on further study and training. Yet there never was a time when there were so many opportunities opening up in overseas territories as there are to-day. We can forget the pessimists who say that the under-developed countries of the world no longer want the white man.

We can forget, too, the present trouble-centres of the British Commonwealth and think of those vast areas where rapid progress has been made towards the growth of modern industry, the improvement of agriculture, the education of local peoples and the consequent rise in their living standards. In 1922 the area of Britain's Dependencies was 2,250,000 square miles; last year the area was still the same even after allowing for those former dependencies which are now self-governing. Perhaps only a statesman can adequately comprehend the full significance of colonial development—apart from a few engineers whose work has taken them abroad and brought them into contact with changes which are a true industrial revolution (the so-called Industrial Revolution was really an evolution). To work on a project such as the Owen Falls hydro-electric scheme in Uganda and to see evidence of the phenomenal rise in the consumption of electricity which can threaten to overtake the capacity of the turbo-generators is to be conscious—almost fearfully conscious—of the industrial awakening of a primitive community.

For as long ahead as anyone would care to forecast, the services of British, American—and Russian—scientists, engineers and administrators will be needed, for although there will be available an increasing number of native experts, the lead in technology which the advanced nations are likely to retain will ensure the continuance of the need. The extent of the British contribution to-day is well brought out in a brochure, "Colonial Development and Welfare, 1946-55," which has been prepared by Mr. Roy Lewis and the Central Office of Information for the Colonial Office, some figures from which are given in a Weekly Survey note in this issue. It is to be hoped that this publication will find its way into many homes, colleges, schools and public libraries; it is most attractively produced, in a style that is quite the reverse of the popular conception of Government publications. It covers a period of ten years, since in April of this year the 1945 Colonial Development and Welfare Act had been in force for just ten years. Soon after the war the Colonial Office had requested the colonial administrations to prepare ten-year development plans. These plans were drawn up locally by the people who would take a major part in implementing them and would ultimately benefit from them. The experience was invaluable in fostering the new spirit and attitude of mind which must be brought out if such communities are spontaneously to welcome the civilised way of life which opens up before them. The development committees that were set up in all territories were encouraged to plan ambitiously. Their projects included the instruction of farmers to achieve bigger output of crops, the construction of dams and reservoirs for the irrigation of the crops and of roads for transporting them, the extension of secondary and higher education so as to increase the number of professional and skilled workers, the consequent increase in primary education so as to take care of future requirements, and, over all, the need to raise the understanding of peasants. Harsh words about British imperialism must sound absurd when confronted by the tangible results of these plans. The fact that the great works which have been carried out, and the additional plans which have been prepared for the future, seldom reach the headlines of the popular press is due simply to the fact that they are never red-hot news, unless there is a strike, a revolt or an international argument over finance.

Sir Raymond Priestley has this week opened our eyes to an even broader horizon. In his presidential address to the British Association he has pointed to Antarctica as an area of the world where Twentieth Century man is making new conquests. He believes that "everything will depend upon the discovery of a worth-while economic objective, and this is not at the moment in sight. The chances are that, for the remainder of this century, Antarctica will remain the scene of investigations in pure rather than applied science. But man may yet find a way to overcome the latent heat of ice and add a seventh habitable continent to the six he already has in thrall." No one is better qualified to express an opinion on prospects in this area than Sir Raymond Priestley, but in spite of his cautious prophesy his review showed that Antarctica, like the colonies, may be developed more quickly than we imagine to-day.

THE INTERNAL-COMBUSTION ENGINE

SOME EARLY STAGES IN ITS DEVELOPMENT

By C. St. C. Davison, M.SC., PH.D.*

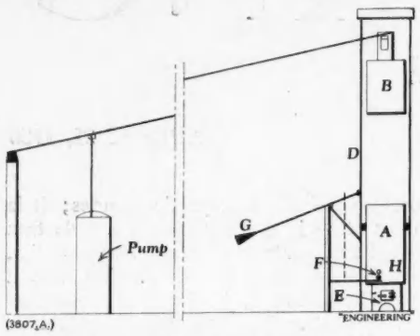

Fig. 1 In 1794, Robert Street sought to drive an engine with gases obtained when spirits of tar or turpentine were heated. The gas would be ignited after mixing with air through a touch-hole (F).

* * *

Plain Words

Low's white horse is turning into an aged grey mare, and as it trots somewhat ponderously to Brighton it is unusually worried by flies. This is the impression conveyed by 275 closely printed pages of the Trades Union Congress General Council's report, taken together with the agenda for the 1956 Congress which starts on September 3. The report contains detailed news on the Council's activities, but most of the principal studies are unfinished, tentative or provisional. Perhaps one of the most revealing—and damning—of the resolutions is tabled by the National Union of Public Employees. It urges the General Council to " take a more active and positive role in our industrial affairs," and, to make this possible, " Congress instructs the General Council to review the organisation of Congress, including the present functions and composition of the General Council " in order to enable the Council and its officers " to exercise more effective leadership in our industrial life."

The most immediate issues facing the Congress are without doubt those of wage levels and redundancy. The largest number of resolutions—13 out of 85—are highly critical of the Government's economic policy and reject any suggestion of wage restraint. The General Council themselves criticise the Government's " excessive reliance " on monetary policy as a means of control but recognise " the need for some reduction of demand " which in their view could be achived more rapidly, and without affecting full-employment, by a reduction of non-essential imports. The recent meetings with the Prime Minister have evidently impressed the General Council's representatives. Yet they do not state their views on voluntary wage restraint. It is plain from this report and from the accompanying resolutions that they could not have supported Sir Anthony Eden's campaign without cutting themselves off from the trade union movement. Instead they have initiated, last March, " a full-scale review of the broad trends in the economic situation in recent years ", which will not be ready in time for Congress. The " magnitude of the problems involved," quoted as the reason for the delay, has clearly overcome the General Council.

The most positive contribution the report makes is on automation. It is welcomed as evidence of technological advance, and a means of improving the standard of living and working conditions. They could not reasonably give less support, for the welfare of their members is the chief interest of the unions. But among the union leaders there is room for more men whose knowledge of technology and management is as full as that of senior industrialists. Knowledge of trade union procedure and shop-floor tactics is not enough.

To-day the internal combustion engine is a commonplace. Existing in many forms, burning heavy oils, petrol, gas or dual-fuels, it may be found in almost every part of the world and in most means of transport. Since Otto introduced his " silent " engine in 1876, development has proceeded rapidly, new arrangements have been tried, refinements added, and more efficient production techniques devised; but before that date progress had been slow and uneven, with the steam engine far in advance. With Otto's application of the Beau de Rochas cycle, the way lay open to the modern high-speed piston engine. In this article the author describes some of the engines and designs that preceded Otto's work, summarising the contributions made by various inventors since the Seventeenth Century, when J. de Haute-feuille used gunpowder as fuel.

The earliest experiments in connection with the internal-combustion engine were carried out by J. de Haute-feuille, the Seventeenth-Century scientist. He burned gunpowder in a closed tank so that a partial vacuum was formed, thus causing water to rise into the tank. Subsequently, he burned gunpowder under a piston in a cylinder and examined the movements of the piston. C. Huyghens also carried out experiments with gunpowder. These experiments were performed a few years before Papin studied the expansion of steam under a piston, and observed that when water was heated in a cylinder, it was converted into steam, which, on expanding, lifted the piston. He then created a partial vacuum by cooling the steam so that the piston was forced down again by the pressure of the atmosphere. Although the steam engine was continually developed, the internal combustion engine remained only in the minds of far-seeing inventors who realised its possibilities. Gunpowder was obviously dangerous as a fuel.

In the Eighteenth Century, however, much was discovered concerning the nature of gases. Warltire was said to have demonstrated the explosive properties of a mixture of oxygen and hydrogen in 1781. Robert Street sought to drive an engine with the gases obtained by heating spirits of tar, or turpentine (1794). The general arrangement of the engine is shown in Fig. 1. It had a vertical cylinder (A) with an open end at the top, and a closed end at the bottom, which was located above a furnace (E). A small quantity of fuel was poured through a funnel on to the hot plate at the base of the cylinder, where it was instantly converted into gas. At the same time, the piston (B) was manually raised, by means of a lever (G), so that air was sucked in to mix with the gas. The mixture was then ignited by means of an outside flame that was held against a touch-hole (F) in the cylinder. The piston was pushed upwards and its movement was guided by the frame (D). The results obtained from this experimental engine must have shown the inventor that it was necessary to have additional engine parts: for example, to measure the correct amounts of fuel and air admitted to the cylinder, for mixing them thoroughly, and for firing the mixture at the right moment.

Phillippe Lebon patented a gas engine in 1801 which was in advance of its time. He proposed the use of coal-gas and air for driving a double-acting engine. The gas and air were to be compressed in separate pumps (L and M) driven by the main piston rod, before they were admitted to the cylinder. Then the mixture was to be ignited by an electric spark. Apparently, this was the first suggestion that the charge should be compressed before ignition but the engine, which is illustrated in Fig. 3, was never made. The manufacture and distribution of coal-gas were still in their early stages, and electricity at that time was little understood by engineers.

A proposal for a small engine that would drive various machines and at the same time serve as an alternative to the steam engine was made by Rivaz in his patent of 1807. His patent drawing, reproduced in Fig. 2, showed a single-cylinder vertical engine fitted to a road-vehicle and driven by a micture of hydrogen and air, or other gases. Although it was a better design than Street's engine it still had only manual control for the quantities of air and gas admitted to the cylinder. The charge was fired by cropping grains of gunpowder on the heated cylinder bottom or by means of an electric spark, as proposed by Volta. The piston, which had a vertical rod con-

* Assistant keeper, The Science Museum, South Kensington, London, S.W.7.

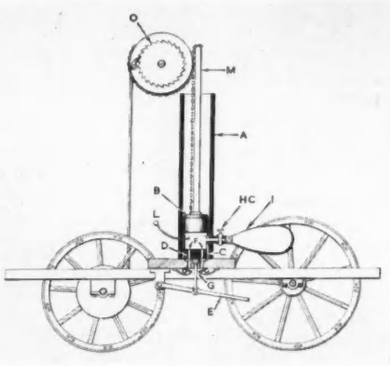

Fig. 2 Hydrogen was to serve as fuel, with ignition by grains of gunpowder or an electric spark, in an engine for propelling a road vehicle proposed by Rivaz in 1807.

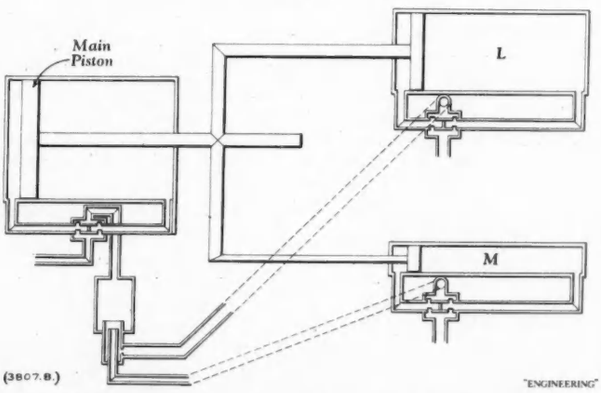

Fig. 3 A double-acting engine, well in advance of its time, was patented by Phillippe Lebon in 1801. Coal-gas and air were to be compressed in separate pumps driven by the engine and the mixture ignited by an electric spark.

nected by two pieces of chain to a pulley, was driven upwards by the explosion of the mixture. Its down-stroke was the working stroke, during which a ratchet was engaged and a second pulley on the front axle of the vehicle was driven by a rope from the first pulley. The driving force was supplied by the weight of the piston and rod.

What was believed to be the first operating gas engine was a small model made by the Rev. W. Cecil who showed it working before the Cambridge Philosophical Society in 1820. Its layout can be seen from Fig. 4. It had a vertical cylinder and two horizontal cylinder-shaped reservoirs, placed end-to-end on the top of the vertical cylinder. A mixture of hydrogen and air was admitted above the piston and into the reservoirs. It was then ignited, and the partial vacuum formed above the piston and in the two reservoirs caused the piston to be pushed upwards by atmospheric pressure. A special instrument measured the amount of combustible mixture supplied to the engine. Cecil's aim in building such an engine was to overcome the drawbacks of the steam engine. These included delay in starting due to the necessity of raising steam in a boiler, and the presence of the boiler and other parts which made the whole unit so large that it could not be transported.

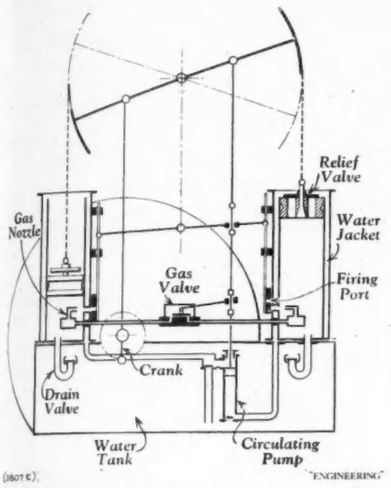

Fig. 5 In most early engines the driving force was provided by the pressure of the atmosphere and the weight of the piston; the burning fuel only served to create a partial vacuum. Samuel Brown made the first full-size gas engines working on this principle early in the Nineteenth Century.

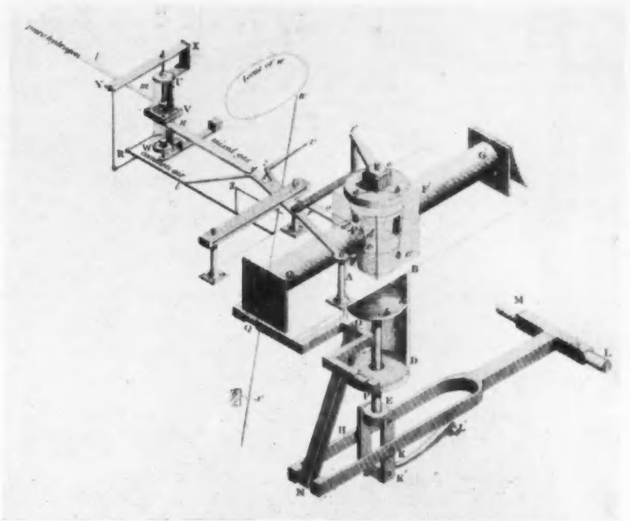

Fig. 4 A model built by the Rev. W. Cecil and demonstrated before the Cambridge Philosophical Society in 1820 is believed to have been the first operating gas engine. A special instrument measured the composition of the combustible mixture, which comprised hydrogen and air.

Many attempts to invent successful internal-combustion engines were made in the years that followed, but the inventors were faced with many difficulties. Their tools and equipment were not precise enough to produce engines that required accurate measuring and ignition of the mixed gases at the correct part of the stroke. They worked in ignorance of each other's discoveries, made in the light of experience, and their inventions were not usually improvements on established designs, but rather were attempts at something new. From the beginning of the century, however, great strides were made in the development of new workshop machines and tools. The design and production of the steam engine were much improved. Inventors of internal-combustion engines naturally borrowed from steam-engine technology and some of their engines resembled contemporary steam engines.

Samuel Brown made the first full-sized gas engines that were driven by the pressure of the atmosphere acting against partial vacuums produced in the cylinders by burning a mixture of gas and air (patents of 1823 and 1826). Although his engines worked well enough they were uneconomical and much too large for the small powers produced. It was stated that they propelled a boat and a road carriage. One of these engines is shown diagrammatically in Fig. 5.

The drawings of the double-acting engine patented by S. W. Wright in 1833, one of which is illustrated in Fig. 6, gave the impression that gas engines had reached a stage of careful calculations and design. Hydrogen and air were delivered to both ends of the cylinder by pumps driven by the engine, and the mixture was ignited when the piston was passing dead-centre by flames applied to touch-holes. The spent

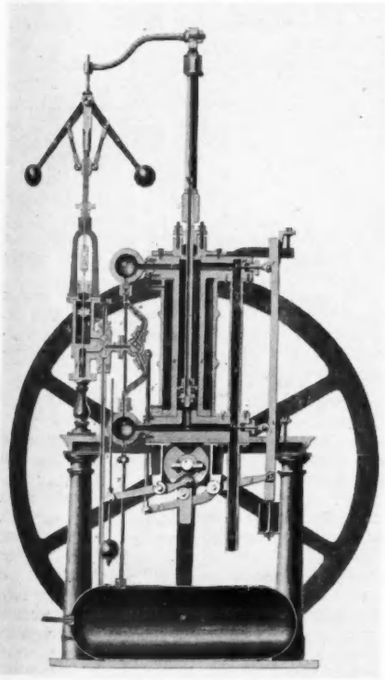

Fig. 6 Accuracy and careful design seem to have been features of the double-acting engine patented by S. W. Wright in 1833.

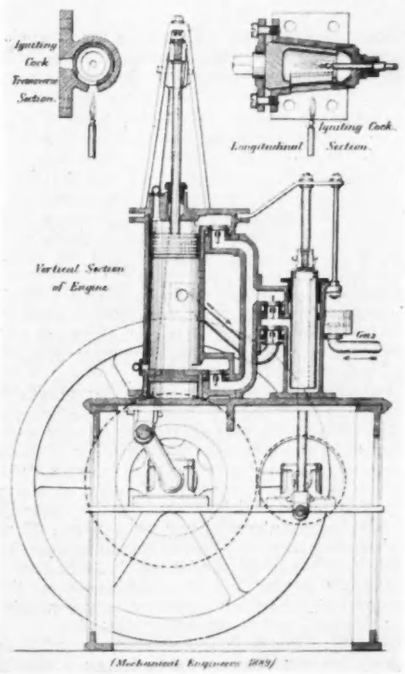

Fig. 7 Compression engines were described in a patent of 1838 by William Barnett. They made use of special flame-ignition cocks.

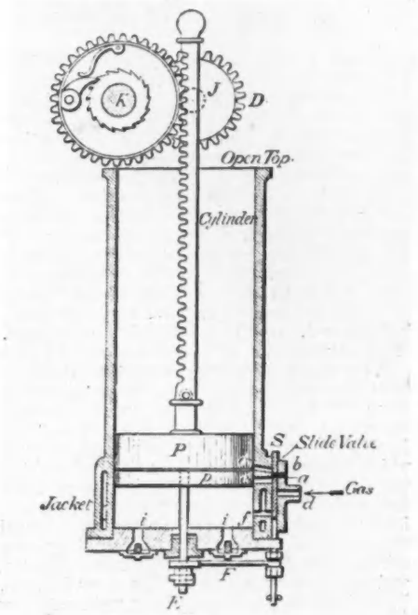

Fig. 8 E. Barsanti and F. Matteucci are said to have built the first free-piston engine in 1857. The piston was free on its upward stroke.

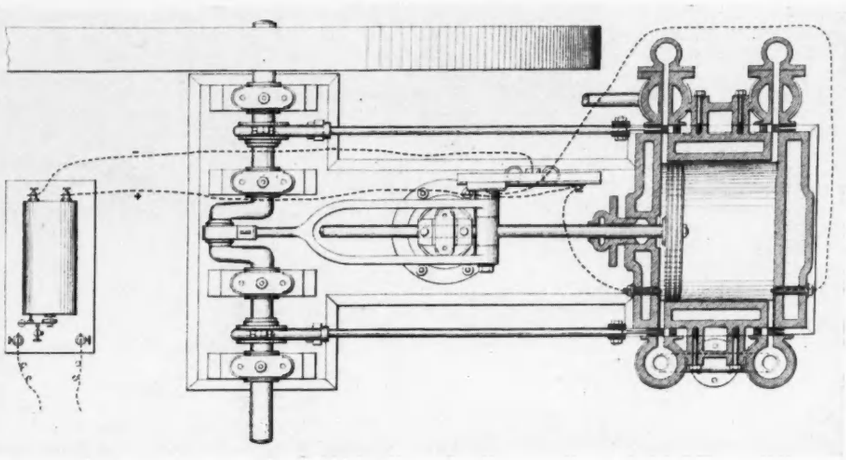

Fig. 9 Slide-valves of steam-engine pattern and sparking plugs were features of a gas engine patented in 1860 by J. J. E. Lenoir. Of horizontal double-acting design, it is thought to be the first internal combustion engine to work with reliability. Delayed ignition, however, caused the piston to move too slowly.

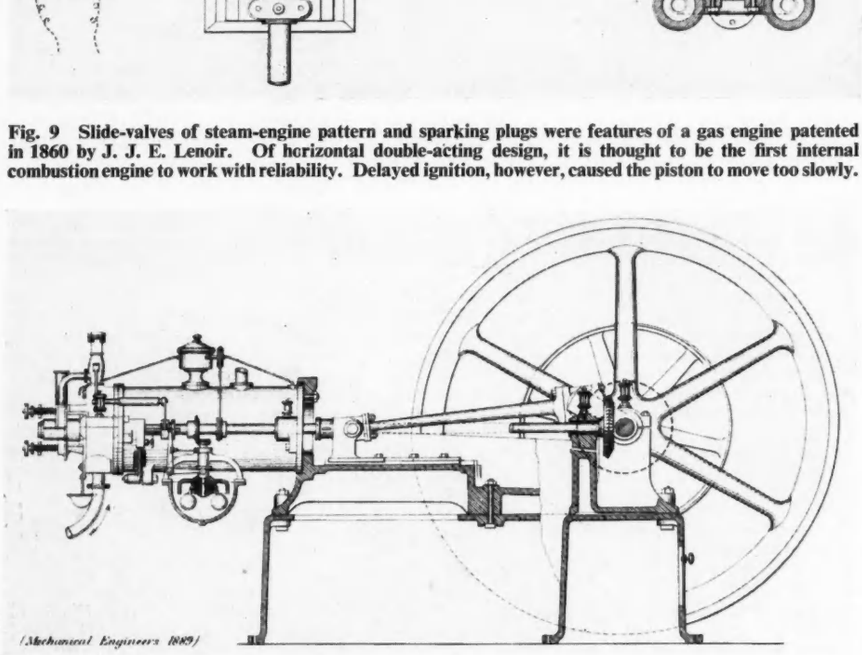

Fig. 10 With Otto's " silent " engine, built in 1876 to run on the Beau de Rochas cycle, the internal-combustion engine entered its modern stage of development. It was smooth running, reliable and economical in fuel, and was suitable for use in workshops where space was limited.

gases were pushed out through exhaust valves near the ends of the vertical cylinder.

Probably the first engine in which the charge was compressed before ignition was made by William Barnett who described single-acting and double-acting compression engines in his patent of 1838 and thus led the way to the modern internal-combustion engine. Two pumps, driven at twice the speed of the main crankshaft, separately compressed the air and the gas, which were then mixed in the main cylinder. Since the mixture was compressed, ignition through the usual touch-holes had to be abandoned and he invented a special flame-ignition cock which was used for many years. It is illustrated in Fig. 7 with the engine.

E. Barsanti and F. Matteucci patented an early free-piston engine (1857). Although it was the first of its type this engine had certain features common to earlier engines. As can be seen from Fig. 8, it had a long vertical cylinder in which a charge of gas and air under the piston was electrically ignited; and it had a piston that was entirely free on the upward stroke. On its down-stroke a rack on the piston-rod engaged with a toothed wheel and provided driving-power arising from the combined weight of the piston and atmospheric pressure. This type of engine, in an improved form, was later re-invented by Otto and Langen.

When J. J. E. Lenoir built his gas engine (patented in 1860), a very definite stage in the development of internal-combustion engines was reached. Shown in Fig. 9, it embodied many principles already well known, and the design incorporated much of steam-engine practice. Tools, machinery, and materials had reached a stage when engines could be made more cheaply and efficiently. The consequence was that Lenoir's engine, which was of horizontal double-acting design, was the first internal-combustion to work with reliability.

Slide-valves of steam-engine pattern admitted air and gas into the cylinder where the mixture was ignited at atmospheric pressure by means of sparking plugs, Bunsen batteries, contact breakers and a Ruhmkorff induction coil.

But although the Lenoir engine was successful it suffered from delayed ignition of the charge, which caused the piston to move at very slow speeds. It required too much gas for a small power-output and thus proved expensive to run. It had the effect, however, of showing inventors the direction in which to apply their talents in developing the internal-combustion engine. How to improve the Lenoir type of engine became the main problem. G. Schmidt and F. Million each separately proposed that compression of the charge before ignition would be very beneficial for efficient combustion of the fuel (1861).

In 1862 Beau de Rochas patented a cycle of operations for gas engines and thus probably made the most important contribution to the evolution of the internal-combustion engine. The majority of modern engines work on this cycle. Among other things, he stated that (1) the gases were to be drawn in during one whole stroke of the piston; (2) the mixture was to be compressed during the following stroke; (3) the mixture was to be ignited at the end of the compression-stroke; followed by the expansion of the burning gases during the third stroke; and (4) the burnt gases were to be discharged during the fourth and last stroke of the cycle.

Beau de Rochas only enunciated this brilliant theory and never built an engine to give it practical confirmation. But engine builders continued improving their engines on the lines of the old principles for some years, and it began to appear that unless something better was produced, the internal-combustion engine would have to leave the field clear for the steam engine. It was then that Otto, who had been making a noisy and slow free-piston engine with Langen, produced his famous " silent " engine (1876), a drawing of which appears in Fig. 10. It was built to run on the Beau de Rochas cycle, and its advantages, which were immediately apparent, included a great saving in fuel, smoothness of running, silence and reliability. The internal-combustion engine had at last reached a stage in which it was welcomed in small workshops where there was no room for a steam engine.

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* * *

NEW TELEVISION CAMERA AT LIME GROVE

Tendency to Instability Reduced

The pick-up tubes in the new Emitron cameras which are being installed in the London television studios of the British Broadcasting Corporation at Lime Grove London W.12, though similar in principle to the former C.P.S. type, are provided with an additional mesh on the scanning side of the mosaic. This greatly reduces the tendency to instability caused by excessive high-light brilliance with the result that the tubes can accept an illumination of ten times the normal peak-white value. Even when instability does set in it is confined to the area immediately surrounding the point of excess brilliance. In fact the former tendency for instability to spread over the entire mosaic (causing the effect sometimes known as " peeling off ") has been entirely eliminated.

This greater resistance to instability enables the new tubes to be worked with twice the previous signal current giving a higher signal-to-noise ratio and an increase in the acceptable contrast ratio.

LIGHTING CONTROL

The normal control of lighting within the new cameras is by a continuously variable neutral density filter, which is remotely controlled. This makes it possible to work with a fixed lens aperture and therefore to maintain a constant depth of field under varying lighting conditions. The use of this filter together with the increased working signal carried will require some increase in the studio lighting for a given aperture. On the other hand, the increased flexibility in the choice of scenery and wardrobe (resulting from the increased contrast range) will be an important advantage. The complete absence of any shading controls, together with the employment of remote control for the neutral density filter, has tended to greatly simplify simplified operation.

Letters to the Editor

ROAD ACCIDENTS

A Pilot Scheme

SIR, In your issue of August 17, 1956, page 197, you refer to the proposal put forward by the Engineers' Guild for the systematic investigation of road accidents, and state that what is required is a sample investigation. The Guild entirely supports this, and, indeed the suggestion was included in the draft of the scheme sent to the Ministry, the last paragraph of which reads:—

"The usefulness of a scheme such as now outlined cannot be doubted, but before its introduction on a national scale, experience of its working, resulting in possible modification, should be gained by the introduction forthwith of a pilot scheme, to be operated and analysed over a period of, say, one year, in one suitable county and one county borough."

A trial in two such areas should yield invaluable information and the small staff necessary (possibly only two engineers and two clerks) could certainly be found. The cost might well be less than that of a single serious accident. It is of the utmost importance that these pilot schemes should be started at once. Every day, on average, 15 lives are lost on the roads and, apart from the human aspect, the economy of the country demands that the effort be made and quickly. There can be few, if any, potentially more fruitful ways of employing a few men.

Your obedient servant,
W. H. GILLESPIE,
(for Secretary).

Engineers' Guild,
78 Buckingham-gate,
London, S.W.1.
August 21, 1956.

★ ★ ★

Obituary

MR. J. W. RODGER

Transformer Design

We regret to record the death of Mr. J. W. Rodger, which occurred in Edinburgh on August 16 at the age of 69. He was an engineer of wide experience, though in the early part of his career he had been principally connected with the design of power transformers.

John Wilfred Rodger was born at Warrenpoint, Co. Down. After studying electrical and mechanical engineering in a number of technical institutions, he served his apprenticeship with Paterson Cooper and Company. He subsequently held appointments in the testing, design and sales departments of Johnson and Phillips, Limited, and later successively became chief transformer designer with Ferranti, Limited, at Hollinwood, and with the Hackbridge Electric Construction Company, Limited.

In 1924 Mr. Rodger joined Bruce Peebles and Company, Limited, in Edinburgh, to inaugurate and develop the manufacture of transformers, an activity which had not previously been pursued in Scotland. As a result a special factory was built, which has since been considerably extended, and staff and workers were trained. He undertook further responsibilities nine years later when he was appointed works manager and chief engineer with administrative and technical responsibility for all the design and manufacturing departments. He was elected a director of the firm in 1941, became general manager in 1943 and subsequently managing director in 1946.

Mr. Rodger was elected an Associate Member of the Institution of Electrical Engineers in 1916 and was transferred to the class of Members in 1938. He was also a Member of Council of the British Electrical and Allied Manufacturers' Association.

Weekly Survey

Cover Picture: *The instrument shown being assembled is a precision wattmeter used for checking and testing other precision type electrical instruments. To obtain sensitivity and stability, a long quartz fibre is used to carry the moving coil under gravity suspension; it may be seen against the man's thumb. The delicate operation illustrated shows the fitting of the gold ligaments which carry current from the quartz fibre to the coil. Gold is used for the ligaments to avoid corrosion and because of its stable mechanical properties; and also because the ligaments must exert only a negligible torque on the moving system.*

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Open-Cast Coal Machinery

A stout defence of the use of American machinery for open-cast working was made recently by the Federation of Civil Engineering Contractors. As is well known in the industry, the Open Cast Executive of the National Coal Board are continually opposed in their efforts to import the largest and most efficient types of American machines, particularly large capacity excavators for overburden removal. The chairman of the Federation, Lt.-Col. T. McMillan, makes a very good case for American machines. First, he states, this type of plant is in regular production in the United States, and manufacturers can offer quick deliveries. Second, such machines yield a very high return in dollars. "One hundred cubic yard capacity of imported plant, costing approximately £1½ million, will produce during its working life at least 10 million tons of coal, thus saving some £70 million, mainly in gold and dollars, on coal imports." Implicit in these comments is that British manufacturers of excavating machinery have to manufacture heavy excavators and drag-lines especially for the job. Their lack of experience of this type of plant may result in teething troubles and mechanical defects which could take years to remedy. Whether well-founded or not, this is certainly the fear of several British contractors.

Some of the figures given by Colonel McMillan on open-cast output make encouraging reading. The cost of open-cast coal, which includes the cost of land restoration, has been virtually stable over the past four years, "despite substantial increases in costs and wages generally." It is much lower than the cost of either deep-mined or imported coal; last year it was 51*s.* 6*d.* compared with 67*s.* 3*d.* for deep-mined and 140*s.* for imported. The output per man, due to the high degree of mechanisation, was four times as high as in the pits.

The frequently heard criticism of open-cast mining as a destroyer of the countryside is answered convincingly. Only 30,000 acres are occupied for open-cast mining at any one time, out of a total 45 million acres; the average value of the coal won per acre is "over 100 times the temporary loss of food production." The restored land is of a very high standard, often with improved drainage installations. Colonel McMillan claims that the target of 10 million tons of coal a year could be substantially exceeded if sites were made available. These are powerful arguments. It would be interesting to hear the other side.

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Money for the Colonies

The colonies are important markets for the British engineering industry and should provide still greater export opportunities as the standard of living is raised. A booklet issued last week and entitled "Colonial Development and Welfare, 1946-55" shows how the money allocated under the Colonial Development and Welfare Act of 1945 has been spent. In all, £100 million was granted between 1946 and 1955, and of this total considerable sums were allocated to agriculture and veterinary services (£17·1 million); health services (£16·9 million); road construction and improvement (£14·9 million); water and sanitation (£11·3 million); and housing projects (£4·0 million). In addition, more than 10 per cent. of the funds granted were allotted to basic research, a most important precursor of continued economic progress in a competitive era. Meanwhile education, no less important, has not been neglected. Figures recently released for grants made last year, to March 31, 1956, show that of a total of £15·1 million allocated in that year, no less than £5·4 million was allotted towards education, and a large proportion of this sum went towards providing facilities for higher and technical training. In particular, £155,000 was granted to help in the construction of a technical college at Nairobi, and £103,000 towards building a new chemical laboratory at the University College of East Africa. The University College of Rhodesia and Nyasaland will benefit to the extent of over £1 million for the provision of new buildings.

The most important aspect of the grants, however, does not lie in their global amount, but in the additional funds which have been attracted for capital investment. Thus it is estimated that up to £60 million per annum has been attracted from private sources during the last two or three years, while expenditure under the Act also provided the incentive for further investment by colonial governments and the Colonial Development Corporation. Indeed, the secondary effects of the grants appear to be much more important than the funds themselves. Already it has been calculated that capital schemes worth more than £600 million have been put into effect with the added help of grants made under the Development and Welfare Act. Evidence that the money is considered to have been well spent is provided by the fact that it is planned to extend the period of the Act to 1960, and allot a further £80 million during the next four years. This, together with £40 million already earmarked, will make a total of around £220 million for the period 1946 to 1960, and raise the average annual expenditure to £24 million between now and 1960, compared with about £15 million to date. It will be interesting to watch the "pump-priming" effects of these increased grants in the next few years. Further comment on the report is made in this week's leading article.

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What's on at Farnborough

Round about August every year the Society of British Aircraft Constructors announces with pride that its annual exhibition at Farnborough—usually staged for the first week in September—is "the largest yet." At this year's exhibition, which opens on September 3 and finishes on September 9, the last three days being open to the public, there are to be 338 manufacturers showing aircraft, engines, instruments, components, materials and equipment in the static exhibition. To the engineer connected in any way with the aircraft industry, it is probably browsing through this static exhibition and meeting old friends which constitutes the main attraction of the annual event, rather than the flying display which draws the public in hundreds of thousands, but which inevitably loses its novelty, despite the occasional appearance of new prototypes, when viewed successively over a period of years.

The flying display is, however, the *raison d'etre* of the S.B.A.C. show and, therefore, we give below a summary of the principal items on the flying programme. It is possible that other attractions may be added to the bill by the time the exhibition opens. The display will begin with a demonstration by 100 troops who will board the Beverley military transport aircraft, constructed by Blackburn and General Aircraft Limited and now in R.A.F. service. The aircraft will take off and, on landing, the troops will demonstrate the speed with which they can unload and get into action.

A series of flying test-beds follow—the Gyron

Sperrin, seen for the first time last year, demonstrated by the de Havilland Engine Company, Limited; this will be fitted with two 15,000 lb. thrust Gyron turbojets. Bristol Aero-Engines, Limited, will fly a Britannia powered by two standard Proteus 705 propeller turbines; one Proteus 755, a more powerful turboprop for later versions of the Britannia; and one Orion—earlier known as the BE25—a two-spool "constant power" propeller turbine of great promise for long-range economical transport aircraft. D. Napier and Son, Limited, will be flying a Canberra test-bed for their Scorpion rocket engine.

Rolls-Royce Limited will have their Tyne propeller turbine mounted in the nose of a Lincoln flying test-bed, and their Avon RA29—destined for the Comet air-liners—will be installed in a Canberra test-bed. The first demonstration of a British thrust-reversal system will be staged by Rolls-Royce in a Hunter aircraft. Before the Rolls-Royce Lincoln test-bed flies, however, two well-established Service aircraft, the Fairey Gannet submarine chaser and the Avro Shackleton long-range maritime reconnaisance aircraft, will appear.

Single and two-seat military and research aircraft will include the Auster Aiglet and Hunting Percival Jet Provost trainers, the Folland Gnat light-weight fighter, the Gloster Javelin all-weather fighter, and several Hawker Hunters, two of which will carry rockets and bombs. Naval fighters under development will be represented by the de Havilland 110 and the Vickers-Armstrongs N.113 aircraft, both of which have now completed their deck-landing trials satisfactorily. The English Electric P1 supersonic fighter will fly over, but will not land, and will be followed by the world-speed-record holder, the Fairey FD2 delta-wing research aircraft.

The Avro Vulcan, the Handley Page Victor and the Vickers-Armstrongs Valiant bombers will then appear—the latter, now in R.A.F. service, equipped with de Havilland Super-Sprites to assist the take-off. The latest improved versions of the Vickers-Armstrongs Viscount and Bristol Britannia air-liners, both of which have recently made their maiden flights, will be followed by the well-established de Havilland Heron feeder air-liner, the Scottish Aviation Pioneer, which is in service in Malaya, and the Armstrong-Whitworth-built Sea Hawk, in service with the Royal Navy and on order for Western Germany.

Two British helicopters to appear in the display have also been ordered by Western Germany—the Bristol Sycamore and the Saunders-Roe Skeeter, which is also on order for the British Army. Other helicopters flying will include the Fairey Ultra-light, seen last year for the first time; the twin-rotor Bristol 173, one of which has recently been delivered to British European Airways for trials; and the Westland Widgeon, now available in an ambulance version, and Whirlwind helicopters, the latter now well established in service.

The flying display concludes with four air-liners in which, for the first time, certain guests of the S.B.A.C. will have the opportunity of flying: a standard version of the Bristol Britannia, a Handley-Page Herald ("D.C.3 replacement"), a Scottish Aviation Twin Pioneer "outback" aircraft, and a Hunting Percival President—a civil version of the Pembroke general-purpose transport aircraft which will be demonstrated as a six-passenger "executive" machine.

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Modern Ships

Mr. Stavros Niarchos, the Greek shipowner, explained recently that all his companies are privately controlled, and that there are no share-holders or public balance sheets to be thought of: "that means that I, in touch with the heads of my companies, can take a decision in half an hour on anything." One of these decisions was not to place any further orders on British yards. Ten tankers, including the biggest afloat, have been built for him by Vickers-Armstrongs at Barrow-in-Furness. The second of the ships, each of 47,750 tons dead-weight, was launched on August 8. A similar size ship ordered from the Bethlehem Steel Company was promised "ready for the water" about 8 months after the laying of the keel had been completed. Six of eight tankers ordered on Japanese shipyards early in 1956 will be ready for service by the early summer of next year. Subsequently, orders for three 65,000 ton tankers were placed with shipyards in Germany and Japan.

Mr. Niarchos said that late deliveries, and a far higher price than originally contracted for, ruled out British shipyards. Quick and reliable deliveries, and the possibility of obtaining competitive and fixed prices, make Germany or Japan "the inevitable choice for further orders." This would remain so as long as British yards took twice as long as their competitors to build a ship and insisted on escalator clauses in their contracts. In his view the quality of British-built ships is very good, but British shipbuilding suffers from an "order-book complex" and requires to be "streamlined, modernised, quickened up." Mr. Niarchos is a friend of Britain, and knows the world's shipyards better than most. His comments should not therefore be lightly discarded.

British shipbuilding still suffers from the after-effects of the disastrous inter-war period. The opportunities to invest heavily in new plant and new techniques have not always been taken. The management-labour relations in many yards leave much to be desired. Yet British shipping is in as great a need of modernising its fleets as the shipbuilders their yards. The expansion of world trade, particularly in raw materials, ensures a high level of freights. If a contraction should come about only modern fleets would be able to compete, and British shipbuilders bear a special responsibility in enabling them to do so. The advantage of modern ships clearly emerges from the latest book published by the American Society of Naval Architects and Marine Engineers, reviewed on page 276. Modern design and construction require imagination and drive as well as knowledge and skills.

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T.I. Concentrate Cycle Manufacture

A major re-organisation by Tube Investments of their cycle manufacturing facilities was foreshadowed by the recent formation of a new company, the British Cycle Corporation. This company will take over and control the resources of T.I. constituent bicycle companies located in the Birmingham area. All manufacture will be concentrated in a large factory at Handsworth which has been recently extended. The directors of T.I. explained that the purpose of this move was "to increase efficiency and to lower costs for the battle for overseas markets which is being joined with foreign competition." Another purpose is doubtless to compete more effectively, both at home and overseas, with Raleigh Industries, who have long enjoyed the advantage of a single large factory and have been exceedingly successful, particularly since the war.

The move will be done in stages, and the company expressed the hope that "when circumstances call for it" employees will be willing to continue their employment in the new environment. As all the factories concerned are in close proximity to one another few are likely to object. The wording of the announcement suggests, however, that some reduction might be made in the total number employed. The companies involved will preserve their individuality and will continue to be responsible for the marketing and development of their particular products.

The Fairey FD2 delta-wing aircraft, holder of the world speed record, which is to appear at the S.B.A.C. show at Farnborough next week.

Such a major change is better understood in the context of the current performance of the British cycle industry. Output has been falling during the past few months, mainly as a result of a decline in sales to the home market. Monthly output during the first 5 months of this year, which averaged about 260,000 units, was some 8 per cent. lower than in the corresponding period of last year. Exports on the other hand were higher, both in quantity and value, by nearly 11 per cent. during the first seven months of the year. On the other hand there is no doubt that competition abroad is becoming more acute, particularly from Japan, and that prices have become very important. An export market worth £30 million a year, and constituting at present over 70 per cent. of total output, is worth fighting for.

Another factor which must have weighed heavily in favour of concentrating output is the great potential advantages to be derived from the introduction of automatic machinery in very large scale production of this kind. The T.I. board are to be congratulated in having, by their courageous decision, strengthened the export potential of the British cycle industry.

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Car Exports

Figures issued last week by the Board of Trade show that exports of private cars in July, at 32,145, were the highest for any month since May, 1955, and for each of the months May, June and July, exports were higher than for the corresponding months in 1955. The increases, however, have not been sufficient to counter-balance reduced exports in the first four months of the year; total exports to the end of July, 1956, at 202,781, show a decline of 12 per cent. compared with 1955. Germany has continued

to hold the position of the world's largest exporter of cars which she gained from this country in November, 1955.

These figures for exports include chassis with engines and C.K.D. (completely knocked down) sets for assembly abroad, but exclude parts and accessories. When an assembly plant is first set up in an overseas country, exports from the U.K. to that country comprise mainly C.K.D. sets, but frequently arrangements are subsequently made for local manufacture of certain components. In order to obtain a complete picture of the export situation, it is necessary to consider exports of parts and accessories, which include much material for assembly in addition to the spares themselves. In the first seven months of 1956, these exports were valued at £33·4 million compared with £26·9 million in the corresponding period of 1955.

The increase of £6·5 million more than counterbalanced the combined fall of £2·4 million in exports of private cars and £2·1 million in exports of chassis for private cars. By contrast, exports of commercial vehicles (including chassis) increased by £8·6 million. It is interesting to note that the decline in exports of private cars in the first six months of this year was accounted for almost entirely by the smaller cars not exceeding 1,600 c.c. In the range 1,600 c.c. to 2,800 c.c., exports rose from £15·9 million in the first six months of 1955 to £19·9 million in the corresponding period of 1956.

In the light of the strong competition from West Germany and import restrictions in many markets, the increase in the value of the combined exports of private cars and of parts and accessories for the first seven months of 1956, is probably a better outcome than was expected a few months ago. There are, however, few prospects of an expansion in exports over the next few months sufficient to offset the decline in home demand. Apart from the factors mentioned above, some relatively new overseas producers, for example, Australia, are themselves beginning to export private cars.

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Radio Developments

The twenty-third National Radio and Television Exhibition, which is now being held at Earl's Court, London, provides an impressive example of the part that these related forms of entertainment are playing in the life of the nation. It also provides illustrations of the technical advances that have been made in the design both of receiving sets and accessories and indicates the lines along which future developments may take place.

Of these advances perhaps the most significant is the first appearance of the transistor in domestic receivers, generally in combination with valves, although there is at least one set in which this important device is exclusively used. Another point of interest is the progress that is being made in the use of printed circuits. This technique is being mainly used in converters and audio pre-amplifiers and in component parts, such as filter units and switches, although one television set has a printed circuit chassis. Numerous other improvements in design of television sets include picture definition and brightness. Better response above 2 megacycles and therefore sharper detail is being sought by the employment of wider band widths, while some cathode-ray tubes, which had hitherto been fitted with ion traps to ensure longer screen life, are now also provided with aluminised screens, the result being an improvement in brightness of nearly 50 per cent. Progress is also to be noted in the use of tubes with electrostatic instead of electromagnetic focus. This change not only eliminates the focus magnet with its adjustments and mountings, but reduces assembly and setting-up times. By deflecting the electron beam through 90 deg., instead of 70 deg., the electron gun has been brought nearer the screen, thus reducing the depth of the tube and cabinet by 2 or 3 in., and so making for compactness.

In the field of sound broadcasting practically all the table radio sets and radiograms have now three or four waveband tuning (one of the bands being very high frequency) for the reception of the British Broadcasting Corporation's Home, Light and Third programmes by frequency modulation. The basic four-band arrangement is a five-valve "superhet" for receiving long, medium and short waves with an extra stage which can be switched in to operate at 10 megacycles. Examples of the attempts that are being made to obtain higher quality sound are also on view. These are generally based on the use of two, three, four and even five loudspeakers, one of which is of the relatively large moving-coil type for handling the lower frequencies and another of an electrostatic type for the higher frequencies. The middle audio range is served by a third, cross-over filters being incorporated so that each unit only receives the frequencies it can reproduce satisfactorily. Among the components on view mention may be made of the great variety of new television aerials, while capacitors and other parts specially designed for use with transistors and employing new plastics dielectrics, such as polyethylene teraphthalate, or ceramics, are also on view.

The more serious side of radio can be appreciated by an inspection of the exhibits of the Royal Navy. These included a Seahawk aircraft, a model of H.M.S. Bulwark showing the various landing systems and the mirror landing aid. The Royal Marines presented a beach landing station such as is set up to enable the beachmaster to receive messages from the landing ships and other landing beaches; while the Admiralty Signal and Radar Research Establishment demonstrate some of the results of their researches into the use of ferrites for radar. The Royal Air Force are showing examples of experimental rockets and guided misiles and the General Post Office a model of the electronic random number indicator equipment (Ernie) for selecting Government premium bonds.

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New Light on Investment

The trend of investment in the United Kingdom is of particular importance to the large section of the engineering industry which is concerned with the provision of capital equipment, since it largely determines the volume of orders for such equipment. But the level of investment is also important in determining the future competitive position of British industry as a whole. In a period of high interest rates, there is some risk that capital expenditure on new plant and machinery may be deferred or may prove uneconomic due to the high capital charges involved.

The Blue Book, *National Income and Expenditure*, issued last week, provides new and interesting information on investment in the United Kingdom. For the first time figures are given of net capital formation, after allowance has been made for capital consumption, i.e., expenditure on maintenance of existing capital equipment. In 1955, while gross fixed domestic capital formation, at £2,161 million, accounted for the relatively high figure of 12·9 per cent. of national income, true fixed investment at home, after deduction of capital consumption, accounted for only 5·9 per cent. of the gross national product. The trend over the last few years, however, has been encouraging. Between 1951 and 1955, the level of net fixed investment at home rose by 56 per cent. Since gross domestic capital formation increased by only 30 per cent. in that period, this suggests that less capital is being consumed relative to what is being put into new investment.

It is, however, clear that the United Kingdom is still well behind her foreign competitors in this most important factor for competitive production. The increases in investment achieved by the principal European countries were discussed in the Weekly Survey note on page 550 of our issue of June 29 last. In addition, doubts have been expressed as to the uses to which the limited British investmen funds are being put. Although showing a notable increase over 1954, expenditure on investment by manufacturing industry still accounted last year for only 26 per cent. of gross fixed capital formation. Housing still accounted for 22 per cent. of British investment in 1955, though the fact that personal expenditure on housing has fallen considerably over the last few years suggests a less urgent need for investment in this field.

Another welcome point made in the Blue Book was that personal spending, which has increased by 19 per cent. in real terms since 1946, has risen less than expenditure on investment. Sterner hire purchase and other credit restrictions have continued to reinforce this trend in recent months. In June, 1956, the level of hire purchase debt outstanding fell to £397 million, compared with £450 million at the end of 1955. While this is a necessary step to curb inflation, there are signs that the decline in sales of goods such as radio sets and electrical equipment is slowing down and there was in fact a small increase in such sales in June. It will be interesting to see whether the Radio Show and subsequent exhibitions in other fields will reinforce this firmer trend in demand.

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Rising Labour Costs

The Treasury *Bulletin for Industry* last week issued a warning on rising labour costs which is particularly relevant to the engineering industry in view of the decision of the Confederation of Shipbuilding and Engineering Unions to press for a substantial wage increase. The *Bulletin* stated that the improvement in the economic position of the United Kingdom, which took place in the first half of 1956, could be most seriously jeopardised by any further increase in costs of production in this country.

Speaking on the wage resolution, the president of the Amalgamated Engineering Union complained that in urging wage restraint the Governs ment had offered no *quid pro quo* on dividend- or bonus shares and added that no trade union could ever agree to refrain from trying to improve its members' living standards when other people were improving theirs. The implication that profits have been rising more rapidly than wages is, however, disproved by figures given in the Treasury *Bulletin*. In 1954, wages and salaries per unit of output in industry as a whole, and profits per unit of output both rose by about 2 per cent.; but in 1955 wages per unit of output rose by 5 per cent., and profits by only 1 per cent. While comparable figures cannot be given for the first six months of 1956, the Treasury argue that there must have been a substantial further rise in labour costs since the index of wage rates in June was 8 per cent. higher than in June, 1955, while the index of industrial production showed no change.

Of particular interest to the engineering industry is the fact that there has been no comparable rise in labour costs in Germany. Over the period 1950 to 1955, labour costs per unit of output rose by only 2 per cent. in Germany, compared with 25 per cent. in the United Kingdom, and between 1954 and 1955 there appears to have been no increase in Germany against a rise of 5 per cent. in the United Kingdom.

In a separate review of the progress of the United Kingdom economy in the first six months of 1956, the Treasury notes that while both capital investment and exports have risen, there has been a fall in output for defence, and expenditure on consumer goods has shown little increase in real terms. There is, therefore, a good prospect of price stability if further inflation of manufacturing costs can be avoided.

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Aluminium Supplies

Contrary to the trend of prices of most of the principal non-ferrous metals, the price of

aluminium has been increased twice during 1956, by £10 per ton in March and a further £8 per ton this month, to £197 per ton. In addition, a temporary surcharge of 30*s.* per ton was imposed in July on all aluminium sold in the U.K., in order to cover the cost of special purchases of dear metal which had to be made outside Canada, making the effective price £198 10*s.* per ton. Nevertheless, compared with a price of £94 per ton at the beginning of the war, the present price is low in relation to prices of most non-ferrous metals, and this has undoubtedly contributed to the high level of demand which has persisted in the United Kingdom for the past two years.

Between 1952 and 1955 world aluminium output is estimated to have increased from 2·1 million metric tonnes to 3·2 million tonnes. Of the latter figure the United States accounted for 1·4 million tonnes, Canada for 0·6 million tonnes and the U.S.S.R. for 0·5 million tonnes. Important additions to capacity are, however, in hand in both the United States and Canada, and it is expected that by the end of 1956 United States capacity will be about 1·7 million tonnes and Canadian capacity 732,000 tonnes per annum. Longer term expansion in Canada, including the development scheme on the Upper Peribonka river in Northern Quebec and completion of the construction programme at Kitimat, are expected to increase Canadian capacity to over 1 million tonnes per annum by the end of 1959. The capacity of the United States is expected to increase to about 2·3 million tonnes per annum by 1958. Outside North America, new plants are under construction or planned in Norway, Brazil, India, Japan the French Cameroons, Jugoslavia and Hungary, but the main increase may well come from Africa owing to the potentialities for cheap electric power in that Continent. If proceeded with, the Volta River Scheme in the Gold Coast is expected to have a capacity of over 200,000 tons per annum, and plans are also being prepared for a large-scale plant in the Belgian Congo.

It is clear therefore that over the next five years there is likely to be a large increase in world capacity for primary aluminium production, and it seems probable that the supply position will ease. Provided, however, there is no great change in the price of aluminium relative to that of other metals, the present rate of increase of consumption should at least be maintained.

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Machine Tools Slow Down

The figures for new orders for machine tools in May, issued by the Machine Tool Trades Association last week, contain cold comfort. While the order book at the end of May, 1956, totalled £104·8 million—the highest figure recorded in the last two years, and about 4·6 per cent. above the value at the end of 1955—this was by no means due to increased demand, since for the month of May, new orders amounted to only £7·1 million, 12 per cent. below the average in the last quarter of 1955. Home orders at £5·5 million were £1 million less than in May last year and export orders have also declined. Since orders for the three months, March, April and May, 1956, were below those for the corresponding months in 1955, it would be expected that the industry would have been able to work off some of its long backlog of orders. In fact, deliveries also declined between January and May, 1956, by 2·5 per cent. Thus the industry has been faced with the paradox of declining orders with a lengthening order book. Delivery dates still average about fifteen months and are of course considerably longer for some types of equipment.

On the question of deliveries, the home market appears to have borne the brunt of delays, since dispatches of machine tools to overseas countries rose slightly during the first five months of 1956. While it is easy to blame declining orders at home on the credit squeeze (a certain number of cancellations have been reported), the fact that imports of machine tools are well above the 1955 level suggests that foreign manufacturers are offering better deliveries and possibly more advanced designs.

German exports of machine tools during 1956 have risen much more than British exports. During the first five months of 1956, German sales overseas increased by 16 per cent., to £21·9 million, compared with the period January to May, 1955. United Kingdom imports from Germany for the first seven months of 1956, at £4·8 million, were 78 per cent. up on the same period of last year. As suggested in this year's "Outlook" article on the machine tool industry, Germany probably has a fair lead in the important field of automation machinery. There is also, despite their high price, still a pronounced liking for American machine tools in this country. Imports from the United States almost doubled in the first seven months of 1956 compared with the comparable period last year. Now that the labour situation in the United Kingdom machine tool industry is becoming easier, there would appear to be a real opportunity to expand production with the object of reducing the long order book and increasing its share of the home market.

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Restrictions on Trade

A further example of trade restrictions which may affect British exporters of motor vehicles and certain classes of machinery is given by recent regulations by the Mexican Government. These provide for import quotas based on the level of imports in a specified period and also lay down that certain articles may not be imported into Mexico unless the exporter undertakes to purchase a specified quantity of Mexican cotton. Among the articles listed are motor cars, sewing machines, office equipment and certain other classes of machinery. These arrangements are reminiscent of pre-war barter agreements, though the Mexican Government describes them as "compensatory exchanges" and draws the distinction that they are not made between the governments of the countries concerned. Foreign car assembly plants were among the first to be affected: they were informed that basic import quotas for the period November 1, 1956, to October 31, 1957, would be granted only if compensatory arrangements for the disposal of Mexican cotton were made through the Banco National de Comercio.

The background of the regulation is provided by Mexican fears of inability to sell the cotton crop following the release of United States cotton reserves for sale on the world market. The first step taken by the Mexican Government was to reduce the *ad valorem* duties on cotton exports as from August 1, but it is apparently considered that this step alone will not be sufficient.

While the immediate effects of the new regulations will be felt by exporters to Mexico of the specified articles, in the long run it seems probable that the chief sufferer will be Mexico herself. The regulations have not been well received by Mexican importers, on whom the onus rests to dispose of the specified amount of cotton, and it is clear that, as long as they are in force, imports into Mexico will be determined less by considerations of quality and price than by the willingness of exporters to accept cotton in exchange.

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Trade with Egypt

A growing number of British engineering companies are expressing concern over the execution and payment for Egyptian contracts. A period of prolonged negotiations may now follow the London conference without, presumably, any relaxation of the financial countermeasures taken by the British Government when the Suez crisis burst upon the world. The Export Credits Guarantee Department have withdrawn their credit cover, the Treasury cannot hold out any hope of sterling being available and the Board of Trade have nothing to add to their statement of August 10, when the restrictions were announced.

Without passing judgment on British policy on Suez, there are certain features in to-day's confused situation which call for comment. The decision to block Egypt's sterling balances was taken at a time when Britain and France clearly envisaged a quick solution, by force if necessary. This is no longer the case. But dollar balances are not similarly blocked and the latest news from Cairo is that the Egyptian Government are taking steps to adapt the structure of their country's external trade to counter the effects of the controls Britain imposed on sterling. Exports to the Soviet bloc are being increased, well above the one third they accounted for of the total Egyptian exports in the first half of this year. This provides a stable basis for closer economic ties, which cannot be in the British interest. It can be assumed that if the dispute drags on and the embargo on Egyptian balances is maintained, orders for plant and machinery now with British firms will be cancelled and placed elsewhere. There is now ample capacity outside Britain and France to supply the textile machines, Diesel engines, pumping sets, agricultural machinery and other supplies Egypt needs. Only if there is a complete cut-off in the supplies of spart parts from Britain, particularly to the textile and farming industries, will Egypt suffer. There is, however, the possibility—in view of the common aspirations of Arab nationalism under Colonel Nasser's leadership—that other Arab countries with substantial sterling holdings may help Egypt to obtain her essential needs.

This country is learning, albeit slowly, that wars—even small cold ones—cannot be fought without the permission of either the United States or Soviet Russia. In the circumstances it might be wiser not, perhaps, to deliver tanks and planes, but to keep trade going in those items which Egypt needs to build up her industry and agriculture. Not to do so may effectively shut out British engineering products from the greatest export market area of the future.

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When Work is Play

The sharp crackle of an open exhaust came from the pits as the engine started. Carefully the mechanic placed the car on to the track and started it off—at 30 m.p.h., for the scene was the demonstration track at the *Model Engineer* exhibition and the car was only a foot long. Once again the exhibition—the 31st of the series, and organised by Percival Marshall and Company, Limited—has gathered together model enthusiasts from near and far. Over 500 exhibits represent over a million hours of work and range from a ship 1½ in. long to a 7½ in. gauge Beyer-Garrett locomotive (under construction) just over 16 ft. long, which when complete will weigh 1½ tons and be capable of hauling a passenger load of about 8 tons. It is expected that over 100,000 visitors will attend the New Horticultural Hall, Westminster, between August 22 and September 1 when the exhibition closes.

The challenge of the miniature has appealed to craftsmen through the ages and models "discover a marvellous pregnancy of wit in the Artificers," to quote a book published 300 years ago. Items which catch the eye of a casual observer include the miniature cycles and tricycles in "Ye Olde Model Shoppe" (a collection of antique models displayed by Mr. W. Appleby); the racing cars mentioned earlier; and a steam-driven locomotive, 7 mm. scale, controlled by radio and having the receiving equipment mounted in the three-coach "Birdcage" set that it hauls.

Radio control also is incorporated in many of the ship models (some even being demonstrated in the pond) and in the aircraft. There is also a radio-controlled motor coach. It is in cases like these that the versatility of the modeller is shown—one man is master of many trades and is allowed to use them all.

ENGINEERING CONTRACTS

3—MOVEMENT OF PLANT AND MATERIALS

By F. H. B. Layfield

This is the third of a series of about ten articles being contributed by Mr. Layfield for the advice of engineers and others engaged on preparing engineering contracts. Previous articles appeared in ENGINEERING, *August* 3, 1956, *page* 137, *and August* 17, 1956, *page* 201.

Every engineering contract falls into a number of stages. One of the most distinct but neglected of these stages begins when plant, equipment and materials are ready to be sent to the site, and it ends when these items reach their destination. Work involved in conveying operations may be said, in some senses, not to be part of the engineer's job and it is for that reason, perhaps, that the arrangements connected with this stage of the contract so often get such little attention. Many of the difficulties which arise in this connection can be avoided if the engineer will decide at an early moment what programme of events he envisages and what arrangements he wishes to have made. Naturally, it is not possible to consider here anything like all the problems which may occur when elaborate, and sometimes bulky, consignments are moved by land, sea and air. Accordingly, comment must be concentrated upon those difficulties which occur most frequently and which can most easily be avoided.

The first thing which the draftsman of the contract wants to know is when the plant and equipment required are to be ready for despatch, and this information is of particular importance in the case of export contracts. The way in which this date is usually established is by stating: "The time given for despatch dates from the receipt by the contractor of the order together with all necessary information and drawings to enable the work to be put in hand." If this form of drafting is to be effective it must be carefully followed through. Obviously, the contract must provide elsewhere for the operative order to be given and the engineer should have a fairly clear idea of the date on which he intends to place the order. It will be prudent, wherever possible, to define exactly what is to be understood by the term "necessary information and drawings," in order to avoid subsequent disputes. The date of the order is the day from which time will be calculated and somewhere in the contract documents, usually in the tender, there should be a statement that despatch is to take place a stated number of weeks thereafter. Not only should a check be made to ensure that the time for despatch is, wherever appropriate, included in the contract but it should also be made certain that that date is still desirable and practicable. The latter precaution is especially useful when there have been protracted negotiations.

The date of the order and that of despatch should be carefully related to that on which shipment is to take place. When the purchaser is to arrange for shipment, it is usual to provide that "No plant shall be forwarded until shipping instructions shall have been given to the contractor." It will also be found worthwhile in most cases to draw up a timetable, to show how the movement of the plant is expected to go because this will help to ensure that the written arrangements, which are so easy to pen, do really make the appropriate provisions.

DELIVERY AT SITE

Somewhat similar considerations apply also to home contracts concerned with the erection of plant. In such instances, the standard forms usually provide that "No plant shall be delivered to the site until an intimation has been applied for and obtained by the contractor from the engineer that the purchaser is ready to take delivery." Normally, the contract in which this clause occurs sets out a completion date and this will spur the contractor to apply for the intimation as soon as he can. There may be times, nevertheless, when the engineer may feel it desirable to insert a proviso to the effect that the application shall not be made later than a specified date. On the other hand, when the application is made, the engineer may find himself unable to give his assent to delivery. In this event, if the contractor is prevented from effecting delivery, either by the due date or at a reasonable delivery date thereafter, various onerous liabilities fall upon the purchaser under the standard clauses. It is, accordingly, most desirable to make sure that dates for delivery and for access to the site are carefully co-ordinated before they are finally settled.

When the time comes for despatch, the plant will need to be suitably packed and it is common form for the contract to stipulate that "The contractor shall include and provide for securely protecting and packing the plant so as to avoid damage under normal conditions of transport." The engineer is the person who must decide if this kind of provision meets his requirements. There may be occasions when both the engineer and the contractor can agree upon a specified method of packing or upon a definite standard of protection. When such an agreement can be reached, it may be helpful to include precise particulars of the arrangement in the contract. The words "normal conditions of transport" leave many questions unsettled. Often, the engineer will desire to avoid some of the more obvious difficulties which arise under the standard clauses by requiring that the contractor shall so pack and protect the plant that it arrives at the site in good working order, and such a statement leaves it entirely to the contractor to choose the means of packing having regard to the proposed means of transport, whether normal or otherwise.

PAYMENT FOR TRANSPORT

There are occasions when confusion can arise over payments for transport, packing, and customs duties, and confusion of this kind often occurs because of a conflict between the several parts of the contract. The standard forms approved by the Institutions of Mechanical and Electrical Engineers and the Association of Consulting Engineers usually contain a clause which states that "The contractor shall include in the total of his tender the cost of delivering the whole of the material f.o.b. [free on board] at the contract port of shipment." This clause is capable of giving rise to a good deal of dispute. While the General Conditions may state that the contractor *shall* so include the cost of transport in his tender, he may in fact not have done so, or he may even have expressly excluded it; there will then be a conflict between the several provisions of the contract which may prove difficult and expensive to resolve. There is only one way to avoid this difficulty effectively, and that is that the engineer should make quite sure that one of two courses is adopted. Either it must be clearly and unmistakably established that the cost of transport *is* included in the tender figures or, if not, the standard clause should be amended so that it sets out the true position. Very much the same can be said about the clause, already quoted, which deals with the cost of packing and protection.

In some printed forms the clause which states that the contractor shall include in the tender the cost of transport f.o.b. at the port of shipment continues "or the site as the specification may define but, unless otherwise agreed, shall not include import duties and customs dues." Here again there is room for doubt. Normally, the engineer will be quite clear as to where he wishes the plant to be delivered and as to who is to pay the cost of transporting it there. The best course, therefore, is for him to instruct the draftsman of the contract accordingly. It is best to adopt the same procedure for the payment of customs and import duties. In one of the standard forms this matter is dealt with in a very clear way; it being stated that "The purchaser shall promptly pay all customs and import duties which may become payable upon importation of the plant into the country in which the plant is to be erected." This kind of clause is to be commended, as leaving the minimum room for doubt. When plant is to be conveyed by sea, most of the difficulties likely to arise in practice are familiar and the procedure involved in effecting shipment well known. Where use is made of air transport, however, unfamiliar problems may be encountered. These are too complex to be dealt with here, and it must suffice to recommend that professional advice be taken where contracts involve air transport.

MOVING GOODS BY ROAD

Road transport also presents snags on occasion, but the principal road transport matter with which the engineer need directly concern himself is the possibility that the contract will give rise to "extraordinary traffic." This is a problem which, in the form discussed here, is peculiar to home contracts. In the normal course of events, the cost of repairing public highways falls upon the inhabitants at large. Where, however, a quite unusual burden is placed on such highways, it has been thought right that the individual persons creating these burdens shall be required to contribute to the cost of repairs. Accordingly, Section 54 of the Road Traffic Act, 1930, provides that the highway authority may recover from any person *by or in consequence of whose order* extraordinary traffic has been created, the amount of the repairs expenses incurred. Generally speaking, this "extraordinary traffic" occurs when either the volume or the weight of the traffic, or the mode of user, is so exceptional as to cause damage and expense, beyond what would be caused by traffic normally using the highway concerned. The wording of the section is such that, intentionally, it is the employer or purchaser who can, among others, be held liable where such traffic arises in connection with the contract. The Institution of Civil Engineers' General Conditions seek to make provision for these liabilities (in clause 30) and the safeguards there set out may often usefully be applied to all kinds of home contracts. In these days, when constructional plant is often very large and heavy, and when prefabricated units are so often used, the engineer may well consider it wise to take two precautions in this regard. In cases where heavy or unusual traffic is likely to be caused by the contract work, it will be advisable to include a general protective clause. In addition, it may often be helpful to make particular provision relating to the use of individual roads or bridges, or both. Particular care is justified in this connection, because it is one of the few instances where an employer or purchaser may be held liable for actions of which they may have little or no direct knowledge.

CHAIN OF RESPONSIBILITY

At all stages of the movement of plant and materials some specified person should be made responsible for their safety and care. Such liability is usually covered by insurance, but, even so, the engineer has two special concerns about this aspect of transport. In the first place, he will wish to be clear in his own mind exactly who is to be responsible for insuring the plant at each individual stage of its journey. It is of particular importance to check that any proposed arrangements do not leave gaps in the chain of responsibility, however small. Thus, for example, if plant is to be shipped, the contract may state that the contractor is not to be responsible "beyond the port of shipment," while the employer, in his turn, assumes responsibility for the goods once they are on board. Obviously

such an arrangement may leave a gap between the arrival of the plant at the port and its reception on board ship. Of course, not all gaps are so obvious as this, but it is often at the very point where a small and insignificant gap exists that miscarriages take place. A schedule setting out the stages in the journey which the plant will make, and showing who is proposed to be responsible at each stage, will help the draftsman to avoid some of these troubles.

Secondly, the engineer will usually wish to be satisfied that the requisite insurance cover for each stage has, in fact, been effected. To this end, it is usual to provide in the contract that the contractor shall produce the relevant policies and receipts "from time to time, when so required by the engineer." It may well be found advisable to make more specific arrangements than this and to require production of the documents concerned at a given time and place before the liability concerned arises.

SUMMARY

An engineering contract sometimes suffers from vagueness in the provisions it makes for the movement of plant and materials from the workshop, depot or factory to the site. Much can be done by the engineer to obviate this vagueness. A clear schedule of dates is the first need and this should set out, whenever practicable, the probable date of the initial order, the date or dates for despatch, the probable shipping or other transport dates, and those for anticipated arrival on site. This last-mentioned date should have special regard to the availability of the site and access to it. Naturally, the schedule will frequently have to be in the form of periods rather than actual calendar dates. Such a schedule is invaluable for checking whether the contract is so drafted that it will bring about the desired results. The schedule must also take some account of the possibility of unexpected happenings.

In these days of increasingly elaborate and sensitive plant, the subject of packing needs careful thought and the more explicit the contract can be made on this subject the better the result is likely to be. Liability for payment for the packing and protection of plant, like payment for transport, should not be left too vague. Clear instructions on both these matters will enable the draftsman to provide a contract which properly indicates the proposed arrangements. It is useful to make sure that the several parts of the contract are not mutually contradictory in this regard.

Problems created by the actual movement of plant are many and various. One matter stands out among transport problems because it is one in which liability may attach to the employer or purchaser for events which he did not directly initiate and of which he may even be ignorant. This is the incidence of extraordinary traffic on roads in this country. The difficulties which may arise as a result of the occurrence of such traffic are normally met by the inclusion of a general protective clause, such as that set out in the Institution of Civil Engineers' General Conditions, or by specific arrangements, or both. Now that much more heavy equipment and plant are moved by road than ever before, it has become increasingly important that traffic matters should receive particular attention. Care and regard for detail are important here, as elsewhere.

Finally, the insurance of plant and materials while in transit also needs to be watched. The stages by which plant is shifted are so varied, and modern means of transport so numerous, that attention must be paid to the individual arrangements which best suit each particular contract. Responsibility for the plant at each stage of its journey should be clearly defined and these stages should leave no period, however short, uncovered. Once liability to effect insurance is plainly set out, it may well be wise to require the production of the appropriate documents at specified times and places which should, of course, be *before* the time when trouble may occur, and not after.

THE MEASUREMENT OF FATIGUE DAMAGE IN MILD STEEL*

By P. G. Forrest, B.SC.(ENG.), A.M.I.MECH.E.

The purpose of the present investigation has been to find whether the measurement of fracture stress after given amounts of fatigue stressing would indicate progressive damage or the rate of crack propagation during fatigue of mild steel. Unnotched and notched test pieces of mild steel were tested in a direct-stress fatigue machine. Some of the tests were run to fracture, while others were stopped after a certain number of cycles and tested to failure in static tension at — 196 deg. C.

A number of investigations have been made on the effect of fatigue on impact strength and the brittle transition temperature. C. W. MacGregor† summarises previous results as follows: "All investigations reported so far which have come to the author's attention are in agreement that very substantial increases in the brittle transition temperature (for those metals having the phenomenon) with cyclic loading may occur when fatigue cracks are present. Most of the investigations are also in agreement that some (but smaller) increase in transition temperature is to be expected even if cracks are not present." It was therefore thought that if a fatigue crack were present in a test piece of mild steel, this would cause a reduction in the brittle fracture strength, so it was decided to carry out static tensile tests at — 196 deg. C. after prior fatigue. Tests have been made both on unnotched and on notched test pieces.

* Communication from the National Physical Laboratory.

† Symposium on the Fatigue and Fracture of Metals, held at the Massachusetts Institute of Technology, 1950.

The material was supplied as hot-rolled 1 in. diameter bars. Before machining test pieces, the bars were heated to 925 deg. C. for 15 min. and air cooled. A standard machining procedure was adopted for all test pieces, the depth of successive cuts being gradually reduced to 0·001 in. For the unnotched test pieces, circumferential hand polishing was used down to 000 emery. The steel has the composition:

Element.	C	Mn	Si	S	P
Content %	0·17	0·72	0·20	0·024	0·022

EFFECT OF PRIOR FATIGUE ON UNNOTCHED TEST PIECES

The fatigue stressing was carried out in a Haigh direct-stress fatigue machine at 2,000 cycles per min. The test pieces used had a test section 0·20 in. in diameter and 0·25 in. long. An extensometer was fitted to each test piece, so that a measure of the dynamic deflection could be made during the test. The static tensile tests were carried out in an Amsler hydraulic testing machine at a strain rate of about 0·0005 per min. For the low-temperature test the test pieces were surrounded by liquid nitrogen.

All the fatigue tests were made at ± 15 tons per sq. in. the endurance limit having been determined previously as ± 14 tons per sq. in. Some of the tests were continued to fracture in fatigue and the average endurance of these was $0{\cdot}8 \times 10^6$ cycles. From static tests at — 196 deg. C., the values of the fracture stress (defined as the maximum load divided by the final area of cross-section at fracture) were 61 and 58 tons per sq. in. for two tests with no prior fatigue, 59 and 63 tons per sq. in. for two tests after 60 per cent. fatigue life, and 62 and 58 tons per sq. in. for two tests after 90 per cent. fatigue life. Similar results were obtained from tests on another bar.

The results thus show clearly that the fracture stress is not reduced by prior fatigue up to about 90 per cent. of the fatigue life. However, as was evident from the values for reduction in area, the material still retained some ductility at — 196 deg. C. and the results cannot therefore be said to prove that no fatigue damage existed.

The variation of the plastic strain occurring per cycle during some of the fatigue tests is shown in Fig. 1. These values are obtained by deducting the elastic strain from the total occurring during a cycle of stress; they represent the width of the hysteresis loop and are proportional to the damping capacity. Even at 98 per cent. life they give no indication of the impending failure. The increase in plastic strain suggests that the material is softening and not work-hardening as a result of the fatigue.

RATE OF CRACK PROPAGATION IN UNNOTCHED TEST PIECES

None of the test pieces in the earlier tests showed any evidence of fatigue cracks, either by observation under a low-power microscope

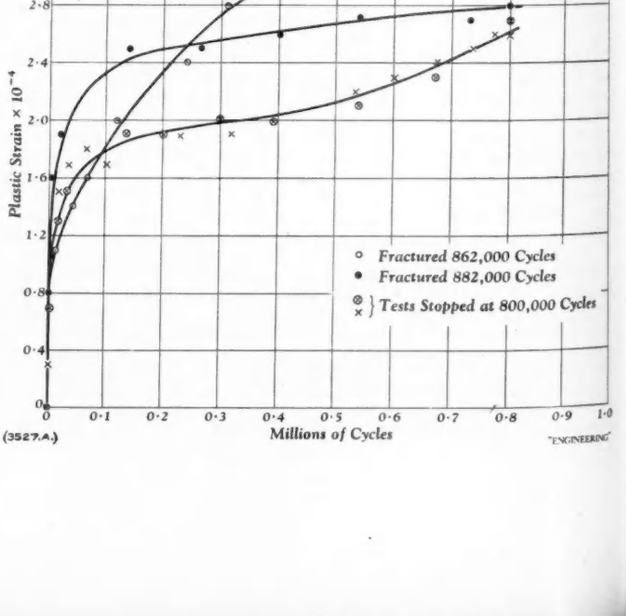

Fig. 1 Plastic strain per cycle during fatigue of mild steel at ±15 tons per sq. in.

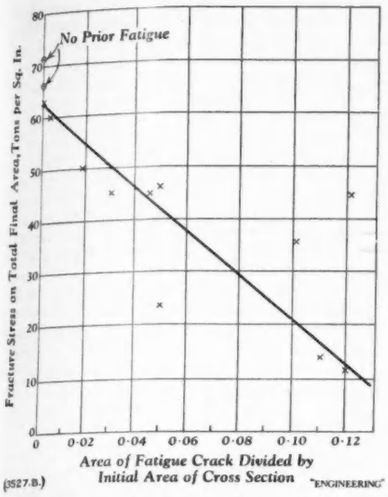

Fig. 2 Influence of fatigue cracks on the fracture stress of plain (unnotched) test pieces of mild steel, at —196 deg. C.

or by a reduction in fracture stress, and it therefore appeared that, for unnotched test pieces of mild steel tested in direct-stress fatigue, cracks do not form until the last 10 per cent. of the life. Some experiments have been carried out to determine more precisely at what stage cracks could be detected.

A test piece was polished with chromic oxide after the standard polishing treatment down to 000 emery. The test piece was then stressed at ± 15 tons per sq. in. (as before); the test was interrupted at intervals and the specimen examined for fatigue cracks with a magnetic crack detector and a low-power microscope. The test piece was examined at the following number of cycles approaching total endurance:—$1{\cdot}01 \times 10^6$, $1{\cdot}13 \times 10^6$, $1{\cdot}26 \times 10^6$, $1{\cdot}39 \times 10^6$, and $1{\cdot}53 \times 10^6$. No fatigue crack was observed at any of these stages and the test piece fractured after $1{\cdot}59 \times 10^6$ cycles.

The next test piece was stressed, again at ± 15 tons per sq. in., for $1{\cdot}26 \times 10^6$ cycles. On the following day, the test was continued at the same stress range and the dynamic deflection, as indicated by the deflection of the extensometer, was watched continuously. The deflection remained approximately constant for about 4 hours and then a slight increase was observed; 30 seconds later the deflection had increased still further and the machine was switched off. The crack detector showed clearly a crack running about 60 deg. round the circumference of the test piece. The test piece was then heated to 450 deg. C. in order to tint the crack followed by a tensile test carried out at — 196 deg. C. The fatigue crack covered 10 per cent. of the cross section; the ultimate tensile strength at — 196 deg. C. was 35·8 tons per sq. in. and the fracture stress on the uncracked area was 39·8 tons per sq. in.

A similar procedure was adopted with the next test piece. The fatigue test was stopped when the dynamic deflection indicated the presence of a crack. The test piece was heat tinted and then replaced in the fatigue machine. A further 26,000 cycles at the same stress range was required to cause complete fracture of the test piece, that is 1·6 per cent. of the total endurance; the heat tinted area covered 12 per cent. of the cross section.

The results indicate that for plain, unnotched test pieces of this material, crack propagation represents only a few per cent. of the fatigue life and that once a crack is formed it spreads very quickly to cause complete fracture of the test piece. It was thought that this result might be attributed to surface hardening of the test pieces produced by the polishing. A number of test pieces were accordingly renormalised *in vacuo* after polishing and then tested in fatigue at the same stress range of ± 15 tons per square inch. The average endurace of four test pieces was $0{\cdot}340 \times 10^6$ cycles, compared with $1{\cdot}35 \times 10^6$ cycles for those not renormalised. The influence of the surface layer on the endurance is thus considerable, but the time of crack propagation in the original test pieces is still small compared with the endurance of the renormalised test pieces.

FRACTURE STRESS AND SIZE OF THE FATIGUE CRACK

A number of further static tests at — 196 deg.C. were made on test pieces containing fatigue cracks and the fracture stress is plotted against the ratio of the area of the fatigue crack to the total area of cross-section in Fig. 2. There is considerable scatter in the results, but it is clear that the fracture stress decreases with increase in area of the fatigue crack. For fatigue cracks covering an area greater than 1 per cent. of the cross-section, the reduction in fracture stress is marked. On the other hand, the fracture stress test is not effective in showing the presence of very small cracks and the method cannot therefore be used to indicate cracks smaller than those which can be seen.

A metallographic examination was made of diametral longitudinal sections of some of the broken test pieces, but on none of these was any crack detected other than the one which caused complete failure. This evidence supports the conclusion that for plain unnotched test pieces of this material, the existence of crack propagation gives rise to a change of only a few per cent. in the fatigue life.

TESTS ON NOTCHED TEST PIECES

The test pieces used were 0·333 in. in diameter with a circumferential 45 deg. V notch of root radius 0·010 in.; the minimum diameter was 0·26 in. The stress concentration factor for this notch has been shown by photoelastic tests to be 3·5. No subsequent heat treatment was given to the notch after machining.

The first series of tests was made at a stress of ± 10 tons per sq. in., that is, the average stress on the minimum cross-section was ± 10 tons per sq. in. Of those tests continued to fracture by fatigue, the average endurance was $0{\cdot}33 \times 10^6$ cycles. Tensile tests at — 196 deg. C. were made on a number of test pieces, which had been subjected to prior fatigue at ± 10 tons per sq. in. up to 94 per cent. of the average endurance. Two test pieces tested without prior fatigue showed fracture stresses of 57 and 65 tons per sq. in. This is only slightly lower than the fracture stress observed on the unnotched test pieces and again illustrates the ductility remaining in the steel at — 196 deg. C., which has decreased the strength reduction factor from the elastic value of 3·5 to a value only a little over 1.

Of those test pieces subjected to prior fatigue, fatigue cracks were usually present if the number of fatigue cycles exceeded 10 per cent. of the average fatigue life. The rate of growth of the fatigue cracks is shown in Fig. 3, where the area of the fatigue crack, as a ratio of the total area of cross-section, is plotted against the amount of prior fatigue. In Fig. 4, the fracture stress is plotted against the amount of prior fatigue and those tests in which no fatigue crack could be detected after the tensile test are differentiated from the others. All five of these tests show values of the fracture stress which are lower than those of the two tests made with no prior fatigue.

Similar results were obtained in a series of tests made at an average fatigue stress of ±8 tons per sq. in. This stress range was close to the fatigue limit; some fractures by fatigue occurred, while other tests ran between 10^7 and 10^8 cycles without failing in fatigue. These were found to contain fatigue cracks, thus confirming that in the presence of a stress concentration, cracks may form during fatigue loading and yet may not propagate.*

The fatigue cracks in the notched test pieces spread round the circumference at the base of the notch. In some test pieces several cracks were observed; in others, which had been subjected to more cycles of prior fatigue, the crack spread the whole way round the circumference. That more than one crack should be present in the notched test pieces is not surprising,

* N. E. Frost, *The Engineer*, vol. 200, page 464 and 501. (1955).

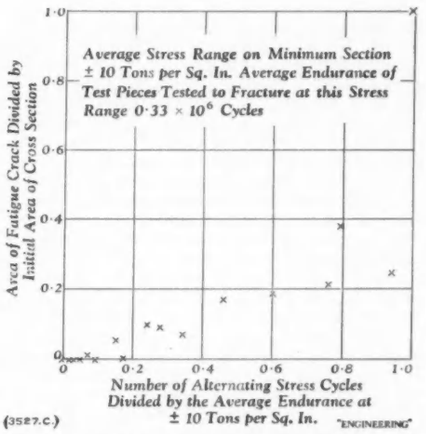
Average Stress Range on Minimum Section ± 10 Tons per Sq. In. Average Endurance of Test Pieces Tested to Fracture at this Stress Range 0·33 × 10⁶ Cycles
Area of Fatigue Crack Divided by Initial Area of Cross Section
1·0
0·8
0·6
0·4
0·2
0
0
0·2
0·4
0·6
0·8
1·0
Number of Alternating Stress Cycles Divided by the Average Endurance at ± 10 Tons per Sq. In.
(3527.C.)
"ENGINEERING"

Fig. 3 Rate of crack propagation during fatigue of mild-steel test pieces containing a notch with a theoretical stress-concentration factor having a value of 3·5.

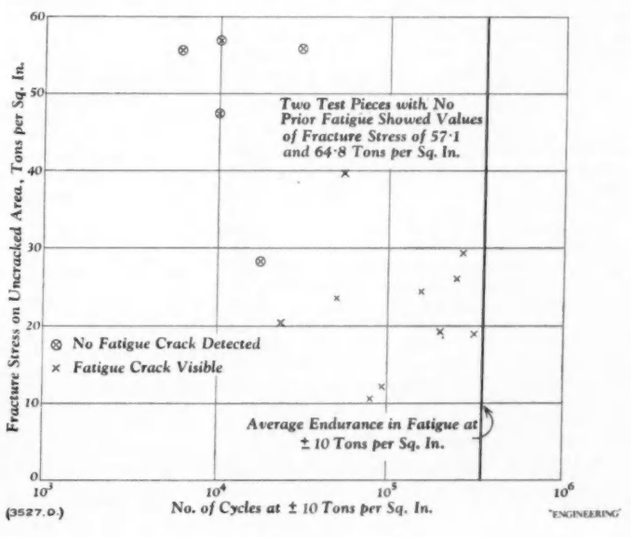

Fig. 4 Influence of prior fatigue on the fracture stress at —196 deg. C of notched test pieces of mild steel, the fatigue stress being ±10 tons per sq. in.

since crack propagation represents the greater proportion of the fatigue life.

CONCLUSIONS

For the stress range investigated, no fatigue crack could be detected in unnotched test pieces until within the last 2 per cent. of the fatigue life. On the other hand, for test pieces containing a notch of stress concentration factor 3·5, fatigue cracks could be detected after 10 per cent. of the fatigue life.

It had been hoped that the fracture stress at −196 deg. C. would be sensitive to very small cracks, so that it would be possible by means of this test to demonstrate the presence of cracks too small to be observed. For unnotched test pieces, however, the smallest fatigue crack observed, covering 0·3 per cent. of the cross-section, caused a scarcely significant reduction in the fracture stress. This may be attributed to the ductility still present in mild steel, when tested in static tension at −196 deg. C.

For notched test pieces, on the other hand, there was some evidence that prior fatiguing caused a reduction in fracture stress, when no fatigue cracks could be seen.

It seems, therefore, that the test might be successful on unnotched test pieces if the material could be made to behave in a completely brittle manner, attained by decreasing the temperature or increasing the rate of loading or both.

Acknowledgments.—The work described above was carried out in the High-Temperature Mechanical Properties Section of the National Physical Laboratory as part of the Research Programme of the Mechanical Engineering Research Laboratory. This paper is published by permission of the Director of the National Physical Laboratory and the Director of the Mechanical Engineering Research Laboratory.

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British Association at Sheffield

OIL AND INDUSTRY*

By A. C. Hartley, C.B.E.

I have chosen the title "Oil and Industry" for this address because I want to describe here at Sheffield the essential part which industry as a whole, and particularly engineering, has played during the first century of oil development, and to emphasise the greatly increased demands which the oil industry will make on other industries for plant and services if it is to make available the fuel, lubricants and other oil products in the quantities on which the very existence of the free world may well depend. I will first describe very briefly some of the highlights of this first century of oil, for it is very little more than 100 years since Dr. Young, a Glasgow chemist, first distilled oil from rich Cannell coal in Scotland and so produced the first mineral oil, and it is less than 100 years since Colonel Drake in 1859 discovered the first natural-oil well in the United States of America. Keen demand for his products soon resulted in Dr. Young working through the available supply of rich Cannell coal, but, with the help of engineers, he improved his plant and methods so as to meet economically the increasing demand by distillation from oil shale, a raw material which, although cheap and abundant, gave only a fraction of the yield obtained from Cannell coal. These developments led to the establishment of the Scottish shale-oil industry, and it is interesting to note that Dr. Young took out patents in which he described the processes of distillation, cracking and refining by chemical treatments, many of which are in use today. By 1865, there were no fewer than 120 shale-oil works in operation. Then, however, oil products from the United States, where there had been even more rapid development following the discovery of the first natural-oil well already referred to, began to compete in the European market, being much easier to produce and refine than oil from shale, and the consequent rapid fall in prices led to the abandonment of many of the shale works.

The steady and continuing development of the shale-oil industry, in spite of all its difficulties, has been of the greatest importance in providing experience for British engineers which has enabled them to play a very large part in the rapid development of the natural-oil industry in many parts of the world following Colonel Drake's discovery well. Within ten years of Colonel Drake's discovery, crude oil was being produced in Rumania, Russia, Italy and Canada, and by 1900 in Poland, Japan, Germany, India, the Dutch East Indies and Peru. Discoveries in Mexico, the Argentine, Trinidad and Persia had followed by 1911.

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EXPLORATION

It is now generally accepted that the original source of oil is organic in nature and that it consists of the bodies of marine organisms and possibly of some plant life formed at the bottom of seas, lagoons, etc., and preserved by the steady deposition of fine grain sealing formation such as mud, clay, lime, etc. There is still, however, much conjecture as to the chemical processes by which they have been changed into oil and gas, and whether this has been by heat and pressure or by the effect of hundreds of millions of years irrespective of heat and pressure, or possibly even by biological processes. The important fact remains, however, that unlike coal, which is solid and remains where it is formed, oil is liquid and may migrate considerable distances laterally and vertically, and only provides a prospective oilfield if it is trapped in reservoir rock or sand, sealed in by impermeable cap rock.

The civil engineer was very early on the scene, to play his part in oil exploration by surveyings map-reading, road-building and providing means of access and subsistence to enable geological surveys to be made. In recent years, these ground surveys had been greatly helped by air reconnaissance, air photography and photo-geological interpretation. Mechanical and electrical engineers and engineers from many of the newer branches of engineering soon entered the field and are playing an increasing part in contributing the improved methods now used for supplementing the efforts of the geologist and making more certain the location of prospective oilfields. They have assisted geophysicists in the development and use of gravimetric, magnetic, electrical and seismic methods of surveying. These depend upon highly sensitive instruments to measure slight variations in gravitational forces of the earth, in the intensity of the magnetic field, in electrical conductivity and in the velocity of transmission of seismic waves in the earth.

The use of one or more of these geophysical methods often establishes the possible existence of favourable underground conditions, but cannot indicate whether oil has ever been trapped in the structure and, if so, whether it remains there now. The only method of proving an oilfield is by drilling wells, but further developments in geophysics are assisting in the location of test wells so that fewer dry holes are now being drilled.

The only equipment available to Colonel Drake when he drilled his first well in Pennsylvania in 1859 was that normally used for drilling water-wells, and it is fortunate that he had only to reach a depth of 69 ft. Mechanical engineering developments just before the turn of the century led to the adoption of the rotary, or mud flush, system of drilling and real progress began to be made. This system, as its name implies, depends upon the more orthodox method of rotating a bit of special design which cuts the formation with a combination of a cutting and paring action imparted by the cutter wheels revolving in the bit head. The bit is connected to screwed drill pipe rotated at surface by a special rotary table, a continuous flow of mud being pumped down the drill pipe and up the annular space, cooling and lubricating the bit and bringing the cuttings to the surface. The mud is loaded with barytes and other materials to specific gravities of 1·25 or more in order to counter-balance the pressure of the oil in the formation and to prevent the oil gushing to the surface when the well is drilled.

In deep wells high pressures are encountered and reservoirs having rock pressures of more than 6,000 lb. per sq. in. can now be explored without difficulty. The very special problem of drilling three miles or more below the surface called for a highly specialised design of casing, drill pipe, rotary tables and particularly of lifting gear, which is the key to the operation. The necessity for very rapid hoisting speeds, so that the drill pipe can be drawn from the hole for changing bits and lowered again with the minimum loss of time, has produced a special design of hoisting gear which has no equal in any other branch of mechanical engineering. The handling of high pressures both in mud, oil and gas calls for very special designs in valves and surface fittings, as well as in the oil-well casing.

The requirements of the oil industry have led to the development of special types of steel in order to produce the toughness and high tensile qualities required at these great depths, where dimensions permit of only the minimum factors of safety. Steam was used extensively in the early days of drilling to drive the draw-works, rotary table and mud pumps, and it is still the most satisfactory power because of its flexibility. It cannot, however, be used economically in oilfields where water is extremely scarce or unsuitable for boilers. In such conditions, the internal-combustion engine and electric-motor drives have been increasingly used. The necessary flexibility to enable steady pulls to be maintained by the draw-works on the drill pipe and steady pressure on the mud, etc., has been obtained by fitting hydraulic couplings. Drilling by electric motors has usually been adopted where a large number of wells have had to be drilled in a fairly restricted area and where it has been possible to obtain sufficient electric power. The depth of the early wells was rarely more than 3,000 ft., but wells are now regularly drilled to 17,000 ft., and in some cases even to more than 20,000 ft.

TRANSPORTATION

Oilfields are usually a considerable distance from the refinery or crude-oil loading terminal site, which must necessarily be alongside deep water to enable products and crude oil to be loaded into ocean-going tankers for delivery to the world's markets. Oil was for many years transported from the wells in oak barrels, but proposals were made as early as 1861 for a wooden pipeline 4 in. in diameter and 6 miles long. The first successful line was made of cast-iron pipe, 2 in. in diameter, with screwed joints. It, too, was 6 miles long, and had steam-driven pumps which delivered about 70,000 gallons of oil a day.

During the 1939-45 war, a 24 in. pipeline, 1,352 miles long with 26 pumping stations, was built in America to carry Texas crude oil to the industrial areas of New York and Philadelphia, and this was followed by another pipeline, 20 in. in diameter and 1,475 miles long, for conveying finished products. These lines worked at 700 lb. per sq. in. pressure and were made

necessary by the severe losses being inflicted on tankers carrying oil along the Atlantic seaboard, but, apart from these losses, they proved so much more efficient in the use of steel, power and men than tankers, that they quickly led to proposals for more large-diameter lines. Every inch in diameter of line gives an appreciable reduction in capital and operating costs, but brings new problems to the mechanical engineer to solve. Seamless pipe cannot be made at present in diameters larger than 26 in., and there is great difficulty in maintaining reasonably uniform wall thickness. Pipe of uniform wall thickness has been made for many years by rolling single steel plates in the form of a circle and then fusion welding the longitudinal seam. The pipe is then subjected to an hydraulic pressure sufficient to stress the steel beyond its yield point and expand the pipe into a die. The pipe is thus made truly circular and straight, and the yield point of the steel is raised.

NOTABLE PIPELINES

Engineers have made a valuable contribution to the oil industry by adapting the submerged-arc welding process for the reliable production of welded and expanded pipe of up to 36 in. in diameter. This increase in diameter has enabled great savings to be made in the capital and operating costs of pipelines and has led to the construction of the 30 in. diameter Trans-Arabian pipeline, 1,000 miles in length, from the Persian Gulf to the Mediterranean, the 30 in., 32 in. Iraq Petroleum Company's line from Kirkuk to Banias, also on the Mediterranean, and many large-diameter lines in North and South America, and in Canada, notably the Trans-Mountain pipeline, more than 700 miles long, from the Alberta oilfields to Vancouver.

The oil industry has encouraged the development of specialised earth-moving, ditching and back-filling machines for preparing the right of way and the trenches, and side boom tractors, cleaning and priming and wrapping machines for handling and protecting the pipe against corrosion. Civil and mechanical engineers have made great contributions to these developments, and more recently electrical engineers have contributed to the development of cathodic protection, which is now almost always applied to pipelines to deal with the inevitable faults or damage to coatings called " holidays."

PUMPING OIL

Reciprocating pumps of the duplex and triplex double-acting ram type were almost universally used for oil pipelines operating at pressures of 600 to 800 lb. per sq. in. in the earlier days, and were driven by steam, compression-ignition engines or electric motors according to circumstances. In 1916, multistage centrifugal pumps driven by steam turbines were installed in the Persian pipelines and proved to be very flexible and capable of running very long periods without shut-down.

The pipelines deliver oil to storage tanks in the refinery or the crude oil terminal tank farms, where all-welded steel tanks are now the common practice. They are usually of 10,000 to 16,000 tons capacity, but some of more than 20,000 tons capacity are now being built. These are 168 ft. in diameter and 48 ft. in height. They are generally surrounded by bunds capable of containing the oil should the tank be damaged. Fixed roofs are used for heavy, non-volatile oils, but steel roofs floating on the oil are now used for crude oil and for light oils in order to reduce loss by evaporation and to reduce fire risk. Great care is now taken to earth all parts of the tanks and protect them against lightning. Cathodic protection is frequently applied to prevent corrosion of the tank bottoms, and tanks are carefully insulated from the pipelines to prevent increased corrosion if they should become anodic to the pipeline system. The pipelines so far referred to have been for handling crude oil, and pipelines for supplying finished refinery products to the marketing depots will now be described.

Pipelines for refinery products have been developed chiefly in the United States, where refined products are handled in larger quantities than elsewhere, and there are now 25,000 miles of products lines in operation. At first, a different line was used for each product, but during recent years it has become almost universal practice to pump aviation and motor gasolene, kerosene, gas oil and light heating oil through a single line, and in some cases butane and propane and heavy fuel oil have also gone through one line. Plugs of water or mechanical separators were put between the different products, but experience has shown that provided the velocity of the oil in the pipe is kept well into the turbulent region, and if the sequence of products is carefully chosen, the amount of co-mingling is tolerable and products can be kept to specification when delivered to the depots. Inhibitors, either water or, more recently, oil-soluble, are introduced into the line at the first pumping station and their amount is regulated to prevent corrosion inside the line. It has been found that the friction factor of the line can be kept low by these means. Facilities are always provided for running scrapers through the line. Products pipelines of diameters from 6 in. to 20 in. or more have been installed and they are operated at pressures of up to 1,000 lb. or 1,200 lb. per sq. in., chiefly by centrifugal pumps.

Standby pumping capacity is installed at the initial station, but frequently not at the intermediate boosting stations, because in series pumping the spare at the initial station can raise the pressure to some extent and help the booster. Electric motor drives are generally preferred where an electricity supply is available, but compression-ignition engines are frequently used with speed-up gears of ratios of up to 10 to 1. Centrifugal-pump speeds of 3,500 r.p.m. are generally used, but in some cases pumps with speeds as high as 5,000 r.p.m., taking 2,500 h.p., have been installed. There has recently been a tendency towards unattended pumping stations, both electric and engine driven, and the sequence of starting and shutting-down operations is automatically timed and controlled and is set in motion and monitored by means of telephones and teleprinters hundreds of miles away. During operation, these stations automatically report to the central control room readings of suction and delivery oil pressures, speeds, temperatures, etc., at prearranged intervals. Where sufficient movement of oil products in one direction is required, bulk pipeline transport has proved to be more economical than rail or road transport, even in average terrain, and much more so in difficult or mountainous country.

WAR-TIME OPERATIONS

During the war, military rather than economic considerations were all-important, and even where the quantities of products required to be moved in one direction were relatively small, pipelines of small diameter were laid to avoid the use of packages or bulk road or rail transport and to ensure regular supplies. Indeed, difficulties in ensuring regular supplies by tins, barrels or jerricans, with losses of more than 50 per cent. in extreme cases, led to the laying of pipelines to follow as closely as possible the advance of the armies in North Africa and elsewhere in 1941. These were " Victaulic " jointed steel lines of 4 in., 6 in., 8 in. and 10 in. diameter laid on the ground, or buried lines with other types of joints. Petrol or Diesel engine-driven pumps were installed to boost the oil every 10 or 20 miles or so. The success of these pipelines and the increasing fuel demands of the modern mechanised army led to the requirements stated by Lord Louis Mountbatten in April, 1942, and referred to by the Rt. Hon. Geoffrey Lloyd, Secretary for Petroleum, for a cross-Channel petrol pipeline to supply the Allied armies when the re-invasion of the Continent took place. This involved the laying of two types of 3 in. pipe which would have been completely uneconomic in peace time, but which eventually supplied 172 million gallons of motor spirit across the Channel with the loss of only 1·1 per cent.

REFINING

Refining is a combination of physical and chemical operations designed to convert crude oil into a series of fractions or cuts and to treat these raw products chemically to remove any undesirable impurities, such as sulphur compounds and unsaturated hydrocarbons. In the early days, separation was achieved by distillation in simple batch stills, which produced a few impure fractions, such as petrol, paraffin and fuel oil. A simple treatment was used to improve the colour and odour, and the products were then marketed. Demands for better products in ever-increasing quantities led to the development of continuous shell still distillation units and later to pipe stills with fractionating columns. These methods produced straight-run motor spirit up to the limit of that naturally available in the crude. In the 1920's, demands arose for a much improved motor spirit, and processes of thermal conversion or cracking were developed. In recent years, further processes, called thermal reforming, catalytic cracking, polymerisation, alkylation and isomerisation, have been developed. These processes enable the proportions and qualities of the various fractions to be adjusted to market requirements. Vast plants requiring power stations, water pumping plants and services on the scale of a large provincial town are required. There is no space now to deal further with this branch of the industry, but some of the products will be referred to later.

TANKER DIMENSIONS

Until the outbreak of the war, tankers were rarely more than 16,000 tons capacity and required a depth of about 32 ft. at low water. Since the war the size of tankers has been increased to 32,000 tons or more. These require a minimum depth at low water of 40 ft. Where this depth could be obtained in a river close to a suitable site for a loading terminal, light jetties were generally used to carry the oil loading pipes and more substantial dolphins were constructed against which the tankers could be berthed. In the early development of new fields, where river loading facilities were not available, sea loading lines were pulled from the shore, in some cases to a distance of two or three miles, to supply tankers moored at buoys where the depth of water was sufficient. These loading lines were, until fairly recently, 10 or 12 in. in diameter, but greater experience in laying sea lines has made it possible to use diameters of 20 or 24 in. with greatly increased throughput. Jetties are used where their cost is justified by the quantity to be handled.

The crude oil and products shipped from overseas oilfields and refineries in oceangoing tankers are discharged at ports or special oil terminals where jetties having an adequate depth at low water can be installed, and the oil is pumped out of the tankers by their own pumps to tanks as near the jetty as possible. Thereafter, oil is distributed by pipeline, road or rail tank cars, or by small tankers or barges for coastwise and inland traffic. There is no space in this article to describe the distribution of products to the smaller depots and eventually to the service pump or to the containers.

THE FUTURE

The main market in the earliest days of the oil industry was for lighting oil or kerosene, and though the widest possible fraction of crude was used, the refiner was often obliged to burn off surplus light spirit for which he could find no outlet. This was the position until about sixty years ago, when the internal-combustion engine was first used to any considerable extent and so created a market for the surplus light spirit. During this period, oil consumption has grown from 8 million tons a year to 700 million tons a year, that is, more than eighty times. During the same period, coal consumption has increased from 500 million tons a year to 1,700 million tons a year, an increase of a little more than three times. Put in another way, the average growth in the use of oil has been 6¾ per cent.

per annum and of coal has been only 2 per cent.

The increase of the world population goes on steadily in spite of wars, and other calamities. In 1900, the population was 1,500 million; by 1950 this had grown to 2,500 million, and it is estimated that it will rise to over 3,500 million by 1980 or soon after. An extra 1,000 million people must therefore be fed, clothed, housed, found employment, moved from place to place, etc., in 25 years' time. Increasing population leads to increased industrial development and so to increased demand for world energy. The world consumed two and one-third times more energy in 1955 than it did in 1920, and the effective consumption of oil fuels has increased almost sevenfold during these 35 years. Thirty-five years ago, oil only supplied one-seventh of this energy, whereas it is now supplying more than half of the effective requirements. More coal was used 30 years ago than it is to-day, and coal's relative contribution has gone down from five-sixths to much less than one-half of the world's energy requirements. Hydro-electricity supplies a relatively small percentage, increasing from 3 per cent. in 1920 to 7 per cent. in 1955.

ATOMIC ENERGY AND FUEL ECONOMY

It is likely that atomic energy will be developed at least as quickly in Great Britain as anywhere else in the world, but the official estimate is that by 1975 it will only produce the equivalent of about 40 million tons of coal. The present consumption of energy in Great Britain in all forms is the equivalent of about 250 million tons of coal a year, and it is estimated that this will have risen by 1975 to about 400 million coal tons. It appears, therefore, that at the best atomic energy cannot by that date provide more than 10 per cent. of our needs, and the average for the world will be much lower. In fact, it seems unlikely that atomic energy will be making as high a percentage contribution in 1975 as hydro-electricity is now making. A recent estimate of the free world's consumption of oil in 1955 is 695 million tons, and it is estimated that this will have risen, even making full allowance for any possible contributions by coal and atomic energy, by about 70 per cent. to 1,200 million tons a year in ten years' time, and to at least 1,600 million tons by 1975.

Modern methods have enabled the kerosene previously used almost entirely for lighting, now to contribute largely to the production of aviation turbine fuel, vaporising oil for agricultural tractors, and to some extent, to the special boiling-point spirit, such as white spirit, used for solvents in the paint industry and for dry cleaning, and more recently for feed stock for petroleum chemicals. The light spirits previously burnt produce the motor spirit used in all petrol engines. The gas produced from straight distillation of the crude is now synthesised and blended with cracked spirit produced by residue cracking processes to provide the aviation spirit required for civil and military piston-engined aircraft. A large market has more recently been developed for using propane and butane as bottled gas for use in caravans, boats and elsewhere when a piped gas supply is not available. It is also used for the cutting of steel.

HEAVY OIL FRACTIONS

The next heavier fraction to kerosene is gas oil, and this produces fuel for the Diesel engines used on rail and road, and for marine and stationary purposes. Very recently, it has been used by the coal-gas industry for the enrichment and augmentation of gas produced from coal. The straight-run residue remaining from the distillation of gas oil, kerosene and light spirit from the crude has long been used as fuel for ships, both naval and mercantile, and is finding an increasing use in stationary power-plants, steel furnaces, industrial heating plants, and other such applications.

Residue oil has long been processed for producing lubricating oil, and in recent years gas oil, paraffin wax, lubricating oils and bitumen have all been produced from the fuel oil by vacuum distillation processes. The gas oil so produced is used to augment supplies of straight-run gas oil, and the paraffin wax has long been used for candles and, more recently, for waxed papers for electrical insulation, and many other uses. Bitumen (asphalt) has long been used for road making and repairing and for water-proofing. Very much work has been done in producing grades of bitumen best suited for the climatic conditions under which they are to be used and they have played a vital part in the development of highway systems.

If the oil industry had not made all these oil products available, it would have been impossible to develop the internal-combustion engines now so widely used, and road transport and aviation would have been impossible.

It has been seen that oil is a very large-scale industry embracing a great range of activities: the finding, production and transportation of the crude oil, refining it, and manufacturing a wide and ever-growing range of finished products, transporting these by land and sea and delivering them to the consumer or retailer everywhere. In carrying out these oil activities, it also has to carry out vast programmes of road-making, housing and ancillary services, health and medical services, education, and co-operate with local governments.

Its research programme is helping in the development of the petroleum chemical industry, which produces solvents, detergents, plastics and synthetic fibres, synthetic rubber, agricultural chemicals, glycerine and many other products—for example, disinfectants, anti-freeze compounds, and a whole range of pharmaceutical products.

WORLD OIL RESERVES

You will be anxious to know whether world oil reserves will be sufficient to support this great and expanding industry. When considering this, clear distinction must be made between what the industry calls proven reserves on the one hand and total estimates of ultimate recoverable reserves on the other. Proven reserves, only taking into account the known quantities of oil in the various oilfields already discovered and which can be produced under existing conditions of present-day methods of extraction, are currently estimated to be 25,000 million tons, and these would be exhausted by about 1975 according to the annual consumption figures already quoted. When we take into account the recoverable reserves, we see quite a different picture. These include amounts of oil which are known to exist outside the so-called proven areas and also large amounts still awaiting discovery in the very extensive potential oil-bearing areas of the world.

It is rather significant that every time this estimate has been made, it has been higher than before. In 1945, the total oil reserves of the world were estimated to be 70,000 million tons; the estimate made in 1954 places the figure at 85,000 million tons, and both these estimates exclude the Continental shelves. Recent data suggest that if these are included, and with the present knowledge of fields discovered under the sea, the estimate might well be 140,000 million tons.

Oil is very closely linked with many other industries, notably with steel. The almost uninterrupted increase in the output of Britain's steel industry ever since the war has been in no small measure due to the greater use of fuel oil. The oil industry, being one of the largest users of steel for its tankers, pipelines and oil equipment of all kinds, has been one of the chief beneficiaries of the larger supplies that have become available and has used them to increase its output of oil.

Oil has played a great part in the development of agriculture by making mechanisation possible. Before the 1914–18 war, very few tractors were available, but by the early 1920's their number had increasted rapidly, particularly in the United States where there were half a million by 1925. At the outbreak of the Second World War, there were 2,500,000 tractors in use throughout the world, and by 1952 about 7,000,000.

Petroleum also assists agriculture by improving insecticides and pesticides by providing kerosene and other light oils instead of water as carriers for toxic substances and so making possible a much greater spread and ensuring an even quantity being distributed more effectively over a wider area. Petroleum is also used for weed-killers, soil conditioners, and for veterinary uses, where it has contributed largely to animal health. It is estimated that about 8 per cent. of this country's consumption of oil products is used for agricultural purposes.

LUBRICATION

But petroleum's most important contribution to industry is the provision of probably 90 per cent. of the whole of the lubricants, without which not only all the motor-cars, aeroplanes, ships and tractors driven by fuel oil, but also all the steam engines, electric trains and coal-fired vessels, would stop. Without oil to lubricate its machines, hardly a single industry, however small, could survive.

The petroleum industry provides a source of mineral oils having very good lubricating properties, and the advantage over the fixed oils of being stable and resisting oxidisation both at normal and elevated temperatures. They are also chemically inert to all the metals used in engineering construction and can experience many cycles of heating and cooling without change of essential lubricating properties. They have the great advantage of being able to be blended and to have their characteristics adjusted in the manufacturing processes to provide oil suitable for lubricating the finest instruments or the heaviest engineering plant. The availability of improved lubricants has made it possible to design engine gears and many forms of machinery with heavier bearing loads, thus enabling space and weight to be saved and so gain great advantages in road, rail, marine and aircraft propelling machinery.

In the early part of this address, I have referred to oil exploration, oil-well drilling, oil production, oil transportation, pipelines for refinery products, etc., and other phases of the oil industry, and you will appreciate how the services of engineering and almost every other profession, and of practically every industry, have been necessary in each of these phases in order to place the oil industry in the position it is today.

You will readily realise that all these services will be required in greater measure in the future, and just to take one example of particular interest to Sheffield, that of steel, it has recently been estimated that the oil industry of the free world, excluding the U.S.A., will require a total of 19 million tons of steel during the next five years, 1956–60, in order to produce, refine and clothe in all its stages of movement from the wells, the oil the consumers will need. About half of this will be finished steels purchased by the industry itself and will fall into three main groups; piping of all kinds and well casing; tin-plate and drumsheet for packaged oil products; and tankage and structures. The shipbuilding industry will require something like 5 million tons to fulfil the tanker orders. It is quite clear that the oil industry's demand for steel will increase substantially, and the rate of increase will probably be somewhere between 6 and 10 per cent. The steel industry is thus faced with the very serious problem of increasing its capacity if it is not to hold back the essential development of the oil industry.

Endless other similar examples may be taken to show the vast effort which must be made in order to enable the oil industry, not only to realise its natural growth, but to take over so much of the percentage now being filled by the coal and gas industries until nuclear power brings relief.

I wish to acknowledge the help which I have received from my former colleagues and from the directors of several of the oil companies for their assistance in preparing this address.

This address is the first of the Section G papers to be published in ENGINEERING. Others will follow during the next few months.

MEASURING TURBINE BLADE VIBRATIONS

DEVELOPMENT OF BARIUM TITANATE TRANSDUCERS

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In a steam turbine, various periodic forces act on the blading. These may arise from unbalanced mechanical forces or from the lack of uniformity of the steam forces applied to each blade. For instance, if, as is normal practice, steam is admitted to the wheel through a number of stationary nozzles mounted as a continuous ring, then each blade will experience a change in force when passing each nozzle. Should a natural frequency range 3,000–6,000 cycles per second for the frequency at which these impulses are received, a resonant vibration of the blading may build up. If this resonance (often in the frequency range 3,000–6,000 cycles per second for stages of large 3,000 r.p.m. machines) occurs at the normal running speed of the machine, then a blade failure by vibration may result.

Ideally, blade vibration could be reduced by eliminating the exciting forces, but this is a condition which is seldom possible in practice. A more practical expedient is to avoid conditions occurring at the running speed; this necessitates a knowledge of the frequency of the principal exciting forces and also those of the natural modes of vibration of the blades.

The frequencies of the principal exciting forces depend on the particular design of turbine and, on a steam turbine stage with full peripheral admission and no steam bleed-off points, they fall into two main groups: low frequencies, corresponding to 2, 3, 4 and 5 times the running speed and high frequencies of n, $2n$ times the running speed, where n is the number of equally spaced nozzle openings.

On a fully bladed wheel an infinite number of modes of blade vibration exists, and it may well be impossible to avoid some resonance occurring at the normal running speed. Fortunately not all modes of blade vibration give rise to trouble in the turbine, although recognition of those which may eventually produce failure if excited by the forces present under normal running conditions, is largely a matter of experience with a particular design. Certainly most of the following conditions need to be avoided:—

(i) A fundamental blade tangential frequency equal to 1, 2, 3, 4, 5 and n times running speed.

(ii) A fundamental torsional frequency equal to 1, 2, 3, 4 and n times running speed.

(iii) A fundamental axial vibration equal to 1, 2, 3, 4 and n times running speed.

In addition it may be necessary to avoid some of the overtones of these vibrations having frequencies equal to n times the running speed.

The danger of resonance occurring at the low frequencies corresponding to 1 to 5 times running speed can usually be avoided by making the blading system sufficiently stiff. For very long blades, however, it may be necessary to rely upon the increase in the frequency of the fundamental tangential blade vibration due to rotation to bring this frequency to a safer value. To avoid resonances occurring with the higher exciting frequency (n times the running speed) accurate knowledge of the vibration characteristics is required[1]. If the frequency characteristics are known, then a choice can usually be made of the number of nozzle openings so that no dangerous resonance conditions occur at the normal running speed.

Calculations allow an approximate estimate to be made of the frequencies of a few of the modes of wheel and blade vibrations but experience has shown that too much reliance must not be placed on calculations alone. What calculations do suggest is that, provided the blade is firmly fixed to the wheel and the shroud band, the change of frequency with rotational speed is negligible for blade frequencies in the range of the nozzle impulse frequency nr cycles per second, where r is the rotational speed in revolutions per second. Thus, in many applications, measurements of blade frequencies on a stationary wheel will provide data of a sufficient accuracy to enable a suitable choice of nozzle openings to be made. On some wheels, however, the vibration characteristics do not allow much latitude in the choice of the number of nozzle openings and, on such wheels, it is particularly desirable to obtain measurements of the blade vibration frequencies at the normal running speed.

For measurements to be made on a rotating wheel in a laboratory test chamber, means have to be found for exciting the blade vibrations and for measuring their frequency. Low-frequency vibrations of long blades are somewhat easier to deal with than those of higher frequencies in the range 4,000 to 10,000 cycles per second, and it is in the excitation and measurement of these high-frequency vibrations that the application of the barium titanate gauge has proved to be a significant development.

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MEASUREMENT PROBLEM

For measuring frequencies of the natural modes of vibration of a bladed turbine wheel it is necessary to have:—

(i) A means of applying to the system an exciting alternating force of any given frequency.

(ii) A method of detecting the vibration response of the system to the given applied exciting force.

For a stationary wheel one of the simplest methods is to attach the armature of a moving-coil exciter close to the root of a blade, energise from a controlled variable-frequency oscillator and detect the resonant frequencies by means of an electro-static proximity pick-up. In the authors' experience it is better to work with a high-sensitivity pick-up and low excitations rather than vice versa. This enables the exciting device to be kept to a small size so that its attachment to the blade does not influence the natural frequencies of the system to any appreciable extent.

Application of this method implies easy access to the blading, and it is where this is not available that practical difficulties arise. Under such circumstances the real need is for a highly sensitive vibration gauge and an exciter which can be stuck on the blade in the same manner as wire strain gauges.

Measurements of vibrations on rotating wheels are, of course, more difficult than on stationary ones. They have been made on a turbine blade by means of a type of wire strain gauge attached to the blade, as for example, by Drew.[2] Here the blade vibrations were excited by the aerodynamic disturbances arising from lack of uniformity of the gas stream, and were of sufficient magnitude to give quite large alternating stresses which could be measured by a strain element of the wire resistance type. Measurements have also been made under laboratory conditions, where the blade vibration has been excited by a stationary magnet or a few air jets or by relying on the unbalancing forces present. The latter method was used by Campbell.[3] In these methods the blade receives an impulsive force each time it passes the magnet, or air jet, and determination of any but the lowest mode of vibration is extremely difficult. For controlled laboratory tests, it is essential that the exciting frequency applied to the moving blade should be continuous and permit the same flexibility of control as for tests on a stationary wheel. This means that both the exciter and the detector should be small enough to be attached to the blade and rotated with it. Under these conditions the blade vibrations emitted will be quite small and highly sensitive gauges are essential.

Fig. 1 Barium titanate strain gauges can be produced in very small sizes and are equally useful for producing or detecting vibrations.

Even with tests on a stationary wheel, where the size and weight of the exciter is of little account provided the vibration frequencies are not significantly changed by the attachment, the maximum stresses produced in a blade under normal laboratory tests are not high. In the authors' tests they were estimated to be of the order of ± 100 lb. per sq. in. With an exciter suitable for use on a rotating wheel, the induced alternating stresses will be less than this, and measurement of stresses of this order is only possible with gauges having many times the sensitivity of a normal wire resistance strain gauge.

PIEZOELECTRIC MATERIALS

The possibility of detecting vibrations by the use of a piezoelectric material in the form of a thin wafer strip attached to the member under test has long held attractions. Such an inherently simple device, highly sensitive to alternating strain, giving as it would a self generated voltage proportional to strain and requiring relatively simple measuring gear, has many advantages over other types of vibration strain gauges. Furthermore, application of an alternating

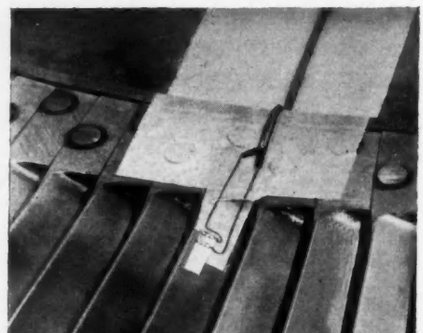

Fig. 2 The gauge can be glued to the blade without materially affecting the natural frequency.

voltage across the material produces alternating strain in the material, so that piezoelectric devices may be used not only to detect vibrations but also to excite them.

The usual single-crystal type of piezoelectric material, such as quartz and Rochelle salt, is a sensitive load-measuring device and it has been used for this purpose in the form of relatively large slabs. Piezoelectric exciters and detectors in the form of probe units have also been used under laboratory conditions for vibration measurements, for example, on gas-turbine blades.[4] Rochelle salt is sufficiently sensitive to be used in the form of thin wafer strips[5] but it can only be used over a limited range of temperature and humidity, and its breaking stress is low. A thin wafer of quartz on the other hand would have an inconveniently high capacitative impedence.

Ferroelectric ceramics, such as barium titanate, are piezoelectric after polarisation in an electric field and have very high dielectric constants, a few hundred times that of quartz. Wafer strips of ferroelectric ceramics thus have a much lower impedance than the piezoelectric elements hitherto available. Like other ceramics, thin strips of the material need careful handling but are not unduly brittle for normal use.

The piezoelectric properties of these materials are temperature dependent, and at a certain critical temperature, usually about 100 deg. C., they disappear completely. The properties can only be restored by re-polarisation at a lower temperature.

BARIUM TITANATE GAUGES

To detect vibrations the direct piezoelectric effect in the gauge material is used, a charge being produced on the surfaces when the material is strained. In particular, strain along the length of a gauge produces a charge on the silvered faces. For a steady strain this charge will leak away, the time constant of the circuit depending upon the measuring equipment used and on the properties and dimensions of the material, so that a pulse output will be obtained when strain is applied and removed at infrequent intervals. If the strain is of an alternating nature and varies quickly enough, leakage of charge becomes unimportant and a voltage-sensitive device connected to the opposite conducting faces will indicate, to some scale, the alternating strain in the gauge. Although unsuitable for the measurement of steady strains, the lower limit of frequency measurement should extend down to a few cycles per second using suitable electronic gear. The upper limit of frequency is set by the resonant frequency of the gauge and should be well above 50 kc. per second.

For fabrication into wafer units, the material is pressed into a desired shape and then sintered at about 1400 deg. C. to form the ceramic. The sintered discs or blocks are cut into wafer-thin strips of appropriate sizes, and surface ground to the required thickness. The opposite faces are silvered, the coating on one face being extended round one edge on to a bare region on the other face. Thin leads are soldered to both metallic surfaces on the same side of the strip. The material is polarised by applying an electric field of the order of 20 kV per cm. across it. Two sizes of vibration strain gauge manufactured in this way are shown in Fig. 1, on the previous page.

The sensitivity of a barium titanate vibration strain gauge to longitudinal strains is very high. Measurements on a gauge 1 in. long, $\frac{1}{8}$ in. wide and 0·010 in. thick, using a wire resistance gauge to measure the strain, gave a sensitivity of about 3 mV per lb. per sq. in. stress in steel for a vibration resonance at 200 cycles per second, the gauge being connected to the input of a Mullard E800 oscilloscope; this is approximately equivalent to 0·1 volts for 10^{-6} units of strain, a few thousand times the sensitivity of a typical wire resistance strain gauge.

This extremely high sensitivity makes a barium titanate gauge eminently suitable for the detection of small vibration resonances. For this it is not necessary to know the actual strain produced and no attempt has yet been made to calibrate the gauges for precise strain measurement. The gauges can, with care, be removed without damage from a component small enough to be immersed in the glue solvent, or from a readily accessible position, so that pre-calibration of each gauge is possible. Calibration would, however, be somewhat more difficult than for other types of strain gauge, since it cannot be obtained by steady strain measurements.

VIBRATION EXCITERS

Excitation of vibrations is carried out using the converse piezoelectric effect in the gauge material, strain being produced when an electric field is applied across the material. In particular, strain is produced along the length of the material when an electric field is applied between the two silvered faces, and if the gauge is firmly glued to a metal surface a strain will be induced in that surface. The application of an alternating voltage at a frequency equal to a natural frequency of the member on which the crystal is mounted should cause a resonance to be excited.

Tests were made initially on a stationary wheel using gauges as already described. A gauge was attached by means of a cellulose-base cement to the blade surface a little more than half-way along its length and, after allowing time for drying, was energised by the output from a variable frequency oscillator. Another wafer unit fixed to the blade near to the root was used to indicate the vibration on an oscilloscope screen. It was found that vibration resonances could be excited and measured without difficulty. With 150 volts alternating current applied to the exciter gauge, the current flow from the oscillator was of the order of 10 mA, changing of course with frequency. The output from the indicating gauge was in the region of 10 to 20 mV at the blade resonance.

Comparison with an electro-dynamic exciter, such as is normally used for static measurements, showed that for this particular blade which was just over 7 in. long, the barium titanate exciter gives less response below 3,000 cycles per second for normal working currents and voltages. At higher frequencies the wafer unit becomes comparatively better and above 5,000 cycles per second is to be preferred.

In order to avoid cross interference between the gauge units it is essential to use screened connections to the units, with the shielding earthed, and to interpose some shielding between the gauge units themselves. It was convenient, in the laboratory arrangements, to have the gauges on opposite sides of the blade and to ensure that the wheel was connected to earth.

There seemed to be no reason why this arrangement should not be suitable for rotational tests and it gave hopes of a simple measuring technique.

TESTS ON ROTATING WHEELS

The wheel tester built at Fraser and Chalmers works for the measurement of vibrations on rotating wheels has already been described[4]. This tester was designed with the primary object of measuring disc vibration frequencies on rotating wheels, using an electromagnetic exciter held stationary in space close to the rotating wheel to excite these vibrations.

The wheel for test is mounted on a short shaft; this shaft runs in two bearings inside a casing which can be sealed by means of a removable top half and evacuated to a high vacuum. The wheel is driven by an electric motor through a shaft which passes through the casing and is connected to the removable shaft by a Bibby coupling. Slip rings of 7 in. diameter, designed for use with magnetic pick-ups, are built on to the driving shaft. Wheels can be rotated in this tester to well above 3,000 r.p.m.

To prepare the wheel for rotation, the screened leads to the gauges were taken radially across the disc surface and glued firmly in position. The lead from the exciter was taken through the shaft coupling to the slip rings integral with the driving shaft and thence to the output from a variable frequency oscillator. The indicator leads were taken through the centre of the shaft to a slip ring unit attached to the free end of the shaft. These slip rings were of conventional design for use with wire resistance strain gauges, with silver-plated rings $\frac{1}{8}$ in. diameter and silver morganite brushes. The signal was passed through a filter unit to an oscilloscope and the frequencies measured using a calibrated oscillator.

Vibrations of the blade were excited and measured at frequencies between 1,200 cycles per second (the fundamental tangential mode) and 11,000 cycles per second at rotational speeds up to 3,000 r.p.m. The stresses induced in the blading by the exciting gauges are small, even

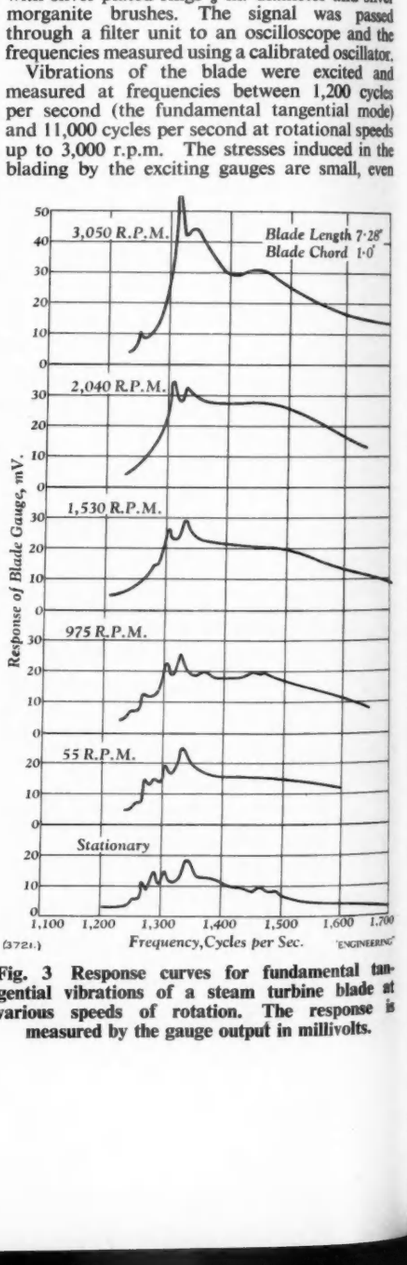

Fig. 3 Response curves for fundamental tangential vibrations of a steam turbine blade at various speeds of rotation. The response is measured by the gauge output in millivolts.

at resonance and are, in fact, generally less than the stresses produced by low-frequency vibrations excited in the wheel by unbalance effects. These latter vibrations are, for this test arrangement, generally less than 300 cycles per second and can conveniently be screened by a high-pass filter.

The output from the indicating gauge at a blade vibration resonance is of the same order as for a static test, i.e., ± 10 to 20 mV, and varies from mode to mode and also with speed due to changes in blade damping. With a signal of this magnitude only minor slip ring troubles were encountered.

No difficulties arose from adhesion of the leads or gauges. The gluing technique used is the same as in normal practice for wire resistance strain gauges and a gauge unit complete with screened connecting cable, such as is shown in Fig. 2, has been successfully rotated at a radius of 24 in. up to a speed of 3,900 r.p.m.

Tests have now been made on many turbine wheels fitted with blades of different length and design. It has been possible to explore the frequency changes which occur as speed is raised, from the lowest vibration mode of long blades at frequencies between 300 to 350 cycles per second, up to high overtone modes with frequencies of many thousands of cycles per second. The measurement of the lowest frequencies requires the greatest care, and certain precautions are necessary to reduce the signal from the self-excited disc vibrations which occur.

If the wheel for test is mounted on a solid cast-iron bush it will become loose at some speed which, for a reasonable interference fit, will be well below 3,000 r.p.m. When this occurs a marked increase in extraneous wheel vibration is usually noted. By mounting the wheel on a flexible bush designed to hold it up to 3,000 r.p.m., or slightly above, the extraneous vibrations at the higher speeds may be substantially reduced.

By suitably tuning the gauges it is often possible to reduce unwanted signals. For instance, when it is particularly desirable to eliminate, as far as possible, the pick-up from nodal diameter wheel vibrations, much can be done by using two barium titanate gauges attached, at the same position, to adjacent blades. The gauges are connected in opposition so that a similar vibratory strain in the two blades will give a minimum response. For a nodal-diameter wheel vibration the movement of two adjacent blades will be nearly, but not quite, the same and as the sensitivity of the gauges may also be slightly different, it is usually necessary to adjust the sensitivity of one of the gauges until the response is a minimum. This is done by carefully removing minute portions of the silver coating of the more sensitive gauge until the response of the gauges to a nodal-diameter wheel vibration is substantially reduced. If this tuning is done on a stationary wheel while it is being excited at a particular nodal-diameter vibration it is possible to reduce the signal to about 5 per cent. of that from a single gauge.

For the long blades on which this method has been used, the decrease in response to a blade vibration excited by a barium titanate exciter attached to one blade was small, and with the signal from nodal-diameter wheel vibrations reduced the blade vibrations were more easily detected and measured.

As an example of the type of measurements which have been made, Fig. 3 shows curves of blade response as measured by a barium titanate wafer unit for the fundamental tangential blade vibrations of a 1 in. chord blade 7·28 in. long, at various rotational speeds up to 3,000 r.p.m. The response is measured in millivolts and as the circuit arrangement was identical for each test the results give a direct indication of the change in damping which occurs in the blade assembly as the speed is changed. The response curves shown are typical of this type of blading system and show that many resonant peaks occur within a small frequency range. It may also be noted that the resonance giving the maximum response at 3,000 r.p.m. is not necessarily the same resonance that gives maximum response on the stationary wheel. This occurs, no doubt, because damping changes due to rotation affect different modes in slightly different ways, but it is clear that if isolated measurements of the frequency for maximum response are made at 3,000 r.p.m. and on a stationary wheel, the apparent effect of centrifugal forces on the blade vibration frequency would be misleading. By a full exploration of the resonance regions such as is indicated by the response curves a much clearer picture of the changes which occur as the speed varies is possible.

CONCLUSIONS

In general the barium titanate gauges can be considered as supplementing rather than superseding other simple types of vibration detectors. For precise vibration stress measurement, precalibration of each gauge before use appears to be necessary, and as this type of gauge cannot be calibrated by applying steady strains, their application for quantitative stress measurements is likely to be restricted to research investigations where the advantages of size and sensitivity are overriding. The gauges do, however, fill the very real need which exists at present for a simple highly sensitive alternating strain detector for resonance indication, particularly for strain levels too small for wire resistance strain gauges.

The use of the gauges as vibration exciter units allows considerable freedom in the positioning of the exciting device even on small components, since the exciting unit may be very small and weigh little more than a conventional wire resistance strain gauge. Because the exciting device is in intimate contact with the member it is desired to vibrate, the input power required to excite the vibrations is kept to a minimum and no elaborate electronic circuitry is required. The gauges permit an easy means of exciting vibrations in lightly damped parts of rotating bodies. The ferroelectric ceramics used to make the gauges lose their piezoelectric properties around 100 deg. C. and an upward extension of this limiting temperature would increase the field of usefulness. There is a possibility that the development of improved materials may give an increase in the maximum working temperature.

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RESEARCH ON MINERALS IN THE UNITED STATES

Funds totalling just over 22 million dols. have been made available to the Bureau of Mines at Washington by the United States Congress, for the fiscal year, 1957. This sum will be used for conducting field studies and for maintaining experimental stations and laboratories in 27 States and in Alaska. It does not include an 8½ million dol. allotment voted by the Congress last year for the Government's share in the 17 million dol. co-operative anthracite mine-drainage programme in the Pennsylvania hard-coal region.

The schedule of investigations on minerals comprises upwards of 70 items and work on a number of these will be speeded up and intensified. Thus research on iron ore will be broadened to include new iron-bearing deposits and to promote further work on the beneficiation and agglomeration of low-grade ores. The Bureau's experimental blast furnace at Pittsburgh will be used in connection with this work.

Other researches on ores will be aimed at developing low-cost methods of producing high-purity vanadium as a by-product of uranium milling operations.

In view of the rapid expansion of the titanium metal and pigment industries, the Bureau is to institute a widespread programme of field investigations and laboratory studies to obtain information on the extent and quality of the reserves of titanium available in the United States. Similar work will also be undertaken for the ores of aluminium and magnesium, the consumption of which is growing steadily.

The known reserves of copper, lead and zinc will be evaluated and the search for new ore beds extended. Although supplies of columbium, tantalum, beryllium and selenium have increased of late years, the demand is continually rising and the Bureau is to expand mining and metallurgical research on these four metals and on a number of others.

The Bureau also conducts investigations on such materials as sand, gravel and stone, abrasives and phosphate rock, petroleum and natural gas, and coal, including its mining and gasification. The production of helium has been carried on for many years under the aegis of the Bureau and the work of extracting this light. non-inflammable gas is financed from its sales, It is interesting to note that the Exell helium plant, Texas, is to be extended and that, at the Amarillo plant, also in Texas, equipment for extracting nitrogen as well as helium from natural gas is being installed. The extraction of the nitrogen will increase the heating value of the gas, obtained as a residue in the helium operations, thus making it more acceptable in the fuel-gas markets.

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AUTOMATIC DRAWBENCH FOR LIGHT ALLOY TUBE

More than ten miles of light alloy tube can be drawn in an hour on a new drawbench designed and built by Head Wrightson and Company, Limited, Thornaby-on-Tees, and installed at the Kitts Green Works, Birmingham, of James Booth and Company, Limited. The drawing cycle, which lasts for 24 seconds, is automatic, and the complete control of the machine is in the hands of a single operator.

The drawbench is over 250 ft. long, and produces tubes up to a maximum finished length of 125 ft. The design allows for normal drawing of three tubes simultaneously, the maximum diameter being 2 in., but tubes up to 3 in. diameter can be drawn one at a time. A 500 h.p. electric motor with a speed range of 600 to 1,200 r.p.m. is provided for the main drive, and the drawing speeds are 225 ft. per minute at 60,000 lb. and 450 ft. per minute at 30,000 lb. pull.

A magazine at the back of the machine holds a supply of tubes which are deposited there by overhead crane ready for drawing. To start the normal drawing cycle, three tubes are dropped into a trough immediately over the drawbench. A pusher ram then forces the tubes over three 100 ft. long plugs at a speed of 350 ft. per minute, and a revolving cylinder carries the plugs and tubes into position opposite the drawing dies. The tubes are then pushed forward into the dies, and the protruding ends are gripped, one in each of three pairs of grips carried on an advancing wagon. The three tubes are thus drawn simultaneously through the dies. While this is taking place the cycle begins to repeat, three more tubes being pushed over another set of plugs ready for drawing. As soon as the drawing of the first set of tubes is complete, the drawing wagon returns to grip the next batch.

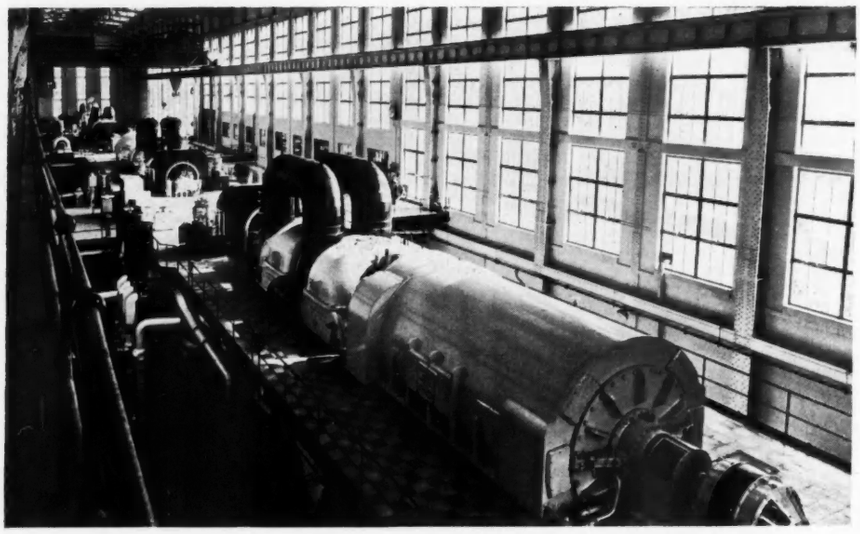


Fig. 1 The turbine room at Carrington A power station, with one of the hydrogen-cooled 60 MW alternators in the foreground.

480 MW CARRINGTON POWER STATIONS

CONNECTION TO 275 KV SUPERGRID

The site of the Carrington power station in the North West, Merseyside and North Wales Division of the Central Electricity Authority was originally acquired by the Manchester Corporation as long ago as 1916. But it was not until 1947 that work was started on the project which is the subject of this article. Carrington will have an ultimate installed capacity of 480 MW. This will be housed in two stations, one of which, with a capacity of 240 MW, was recently opened by Sir William Walker, a past chairman of the Manchester Corporation Electricity Committee.

The Controller of the Division in which Carrington is situated is Mr. A. R. Cooper, the chief generation engineer (construction) Mr. C. R. Watson Smyth and the Station superintendent Mr. J. R. Appleton.

The site is bounded on the north by the River Mersey and on the west by the Manchester Ship Canal. Owing to the nature of the underlying strata, some 7,850 reinforced concrete piles of the cast *in situ* type had to be driven; each pile having an overall diameter of 18 in., a working load of 50 tons and an average length of 30 ft. The superstructures of the main buildings, which are 480 ft. long by 275 ft. wide, are of structural steel with facings of brick and artificial stone.

Coal is brought into the station both by rail and road. It is discharged from the railway trucks by side tipplers on to a system of belt conveyors which have a capacity of 400 tons per hour and is thence delivered into one of seven 1,000 ton bunkers. Alternatively, it can be delivered to a store with a capacity of 206,000 tons.

STEAM RAISING PLANT

The steam raising plant consists of seven boilers, four of which were installed by Babcock and Wilcox, Limited, and the others by John Brown Land Boilers Limited. The latter were the first to be designed and erected by that company for the Central Electricity Authority. All the boilers are of the high-head natural-circulation radiant-heat type and have an output of 360,000 lb. of steam per hour at a pressure of 940 lb. per sq. in. and a temperature of 920 deg. F. Each is fired from four Babcock and Wilcox pressurised pulverisers as these are less prone to blow-backs than those of the suction type. Each pulveriser supplies two triple-port horizontal inter-tube burners, which are arranged in line on one side of the boiler. In addition, there are four automatic retractable burners with electric ignition and pressure atomisation for starting up.

All the boilers are of the single-drum type with the pressure parts slung from the roof steelwork so that expansion is downwards from drum level. The superheaters are of the multi-loop type with tubular attemperators between the primary and secondary sections. The economisers on the first four boilers were manufactured by Babcock and Wilcox and those on the other three by E. Green and Son, Limited. The air heaters were installed by James Howden and Company, Limited. The electrically driven primary, induced and forced draught fans were manufactured by the same firm, the motors for the second and third being provided by Laurence Scott and Electromotors, Limited. The supply of fuel, the steam and furnace pressures and combustion air is automatically controlled and the main dampers are remotely operated by Lockheed hydraulic mechanisms from panels on which switches for starting and stopping the auxiliary motors are also mounted.

The flue gases pass through two-stage Lodge Cottrell electrostatic precipitators of which there are two per boiler into two 350 ft. brick chimneys. Both the grit collected in the precipitators and the boiler ash is washed into a sump where it is crushed. The resulting slurry is then pumped into one of five lagoons which are formed by a bund of blast-furnace slag. When the ash has settled the water is drained off and the ash itself is taken away by road.

GENERATING EQUIPMENT

The generating plant in the A station consists of four Metropolitan-Vickers units each with an output of 60 MW. Two of these are three-cylinder machines while the other two are of an improved two-cylinder type with three bearings. An advantage of the latter arrangement is that it enables a saving to be made in the length and it is therefore also being adopted in the plant for the B station. A general view of the turbine room is given in Fig. 1.

The turbines, which are of the impulse type and run at a speed of 3,000 r.p.m., are directly coupled to hydrogen-cooled alternators which generate three-phase current at 11·8 kV. They exhaust into two twin-flow condensers with a cooling surface of 60,000 sq. ft., the vacuum in which is maintained by two 100 per cent. steam-operated three-stage air ejectors per set and one single-stage quick-start unit. Some of this auxiliary plant is illustrated in Fig. 2.

Water for cooling purposes is drawn from the

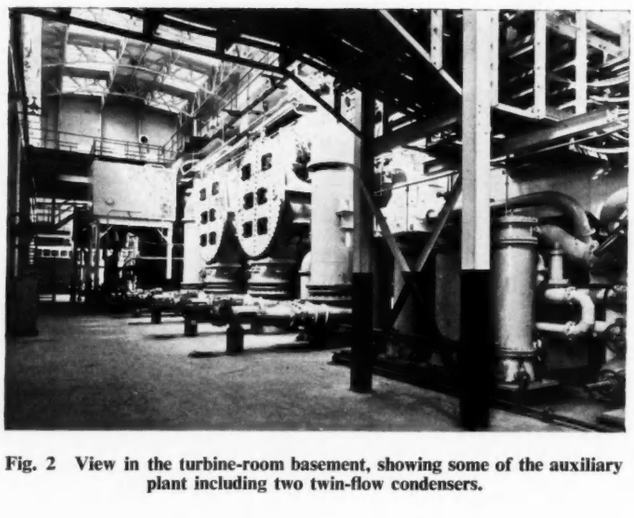


Fig. 2 View in the turbine-room basement, showing some of the auxiliary plant including two twin-flow condensers.

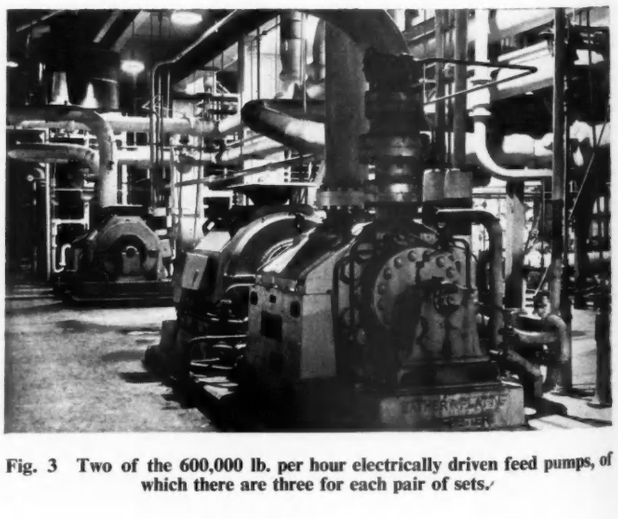


Fig. 3 Two of the 600,000 lb. per hour electrically driven feed pumps, of which there are three for each pair of sets.

Manchester Ship Canal through rough and fine screens into suction ducts by eight Mather and Platt electrically driven pumps with a capacity of 26,100 gallons per minute at a head of 48¾ ft. It is delivered thence to the condensers through two 78 in. steel pipelines and is then returned by gravity through two 8 ft. 3 in. by 6 ft. 6 in. reinforced concrete ducts and over a side discharge weir to the canal. To avoid overheating the outfall has been placed about half a mile down the canal from the intake.

The condensate from each set is treated in two low-pressure and two high-pressure heaters.

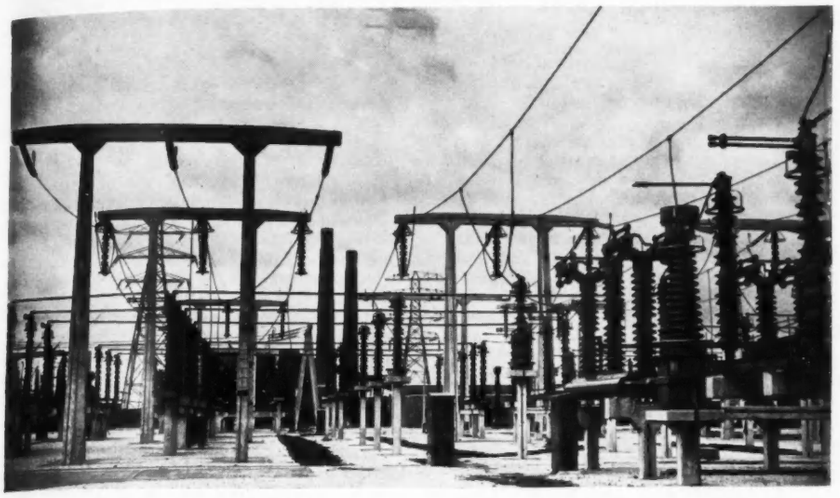


Fig. 4 275 kV substation through which connection is made to the 132 kV network from the supergrid.

There is also a gland steam heater and a high-level full-duty de-aerator direct-contact heater. The condensate is delivered to the boilers by three electric and one steam-driven feed pump, as shown in Fig. 3, for each pair of sets, all the pumps having a capacity of 600,000 lb. per hour. The final feed water temperature is 380 deg. F. on Nos. 1 and 2 sets and 385 deg. on Nos. 3 and 4 sets.

The generating sets are equipped with the latest type of Metropolitan-Vickers turbovisory gear which shows the eccentricity and speed on one recorder and the differential expansion of the rotor, the load, the total turbine expansion, the differential temperature and the total steam temperature on the other.

ELECTRICAL SYSTEM

The alternators are connected to the national grid through 75 MVA transformers which are situated in the 132 kV substation compound. This substation forms a focal point for overhead lines to Warrington, Knutsford, Crewe and South Manchester. There are also connections to Kearsley power station and to the adjoining 275 kV substation. The 132 kV substation is of the double-busbar type and is equipped with Metropolitan-Vickers air-blast circuit-breakers with a rupturing capacity of 3,500 MVA and manually operated isolators. There are also by-pass isolators which enable a circuit-breaker to be taken out of service while the line remains on load. The normal working air pressure of the circuit-breakers is 325 lb. per sq. in. and the storage capacity of the air receiver 1,200 cub. ft. at normal temperature and pressure. This is sufficient for two operating cycles. The compressor plant consists of four three-stage units and two banks of four storage vessels working at 600 lb. per sq. in. Each of these vessels has a capacity of 3,280 cub. ft. of free air, which is sufficient for nine closing and opening operations.

The 132 kV substation is connected to the 275 kV substation, about a quarter of a mile away, by two overhead lines. This substation—an illustration of which appears in Fig. 4—will be the main point of interconnection between the 275 kV supergrid and the Manchester, North Cheshire and South Lancashire areas. Its present equipment consists of four 120 MVA 275/132 kV auto-transformers of Metropolitan-Vickers manufacture, which are wound star/star and also have a tertiary delta winding. They are provided with remotely operated tap changing equipment and with forced cooling. Protective gear for the transformers and lines is housed in a relay room on the site.

275 kV SWITCHGEAR

The 275 kV switchgear is of the air-blast type with eight circuit interruptions in series per phase. The rated current is 1,200 amperes and the rupturing capacity 7,500 MVA. Owing to their size all the isolators are operated by motors and those that may have to be opened in emergency are remotely controlled. These isolators, which are of English Electric manufacture, operate under oil pressure which is generated by an electrically driven pump. Their rated current is 1,200 amperes and electrical bolt interlocks prevent inadvertent operation. The compressors are similar to those on the 132 kV switchgear. The air is stored in two groups of six air receivers at a pressure of 600 lb. per sq. in., and the capacity of each group is 3,264 cub. ft. of free air. The pressure is reduced to 325 lb. per sq. in. for operating purposes.

The switchgear for both 132 kV and 275 kV is operated from the same control room. Control of the 275 kV equipment is effected by a 50 volt direct-current system over telephone-type multicore cables.

The motors driving the auxiliary plant in the station are supplied from 7·5 MVA 11/3·3 kV transformers, one of which is directly connected to each main alternator and is controlled by English Electric switchgear. An alternative source of supply is provided by two 10 MVA 132/3·3 kV station transformers, the primaries of which are connected to the 132 kV busbars. All the auxiliary switchgear is controlled from a separate control room.

The principal contractors engaged in the construction and equipment of the station were:

Taylor Woodrow Construction, Limited, Southall, Middlesex, for the site excavation; A. Monk and Company, Limited, Warrington, and M. J. Gleeson (Contractors), Limited, Sheffield, for the foundations; W. and J. R. Watson, Limited, Edinburgh, and M. J. Gleeson (Contractors), Limited, for the superstructure; W. and J. Jenkins and Company, Limited, Retford, for the coal handling plant; Babcock and Wilcox, Limited, Farringdon-street, London, E.C.4, for the ash and dust handling plant and for four of the boilers; John Brown Land Boilers, Limited, Clydebank, Glasgow, for the remaining three boilers; Metropolitan-Vickers Electrical Company, Limited, Manchester, for the turbo-alternators, condensers and feed heaters; Mather and Platt, Limited, Manchester, and G. and J. Weir, Limited, Cathcart, Glasgow, S.4, for the feed pumps; Mather and Platt, Limited, for the circulating water pumps; Ferranti, Limited, Hollinwood, for generator, station and auxiliary transformers; Bonar, Long and Company, Limited, Dundee, for auxiliary transformers; Metropolitan-Vickers Electrical Company, Limited, for the 275/132 kV transformers and the 132 kV and 275 kV switchgear; English Electric Company, Limited, Kingsway, London, W.C.2, for auxiliary switchgear; Automatic Telephone and Electrical Company, Limited, Liverpool, for supervisory control gear.

NON-MAGNETIC AIR COMPRESSOR

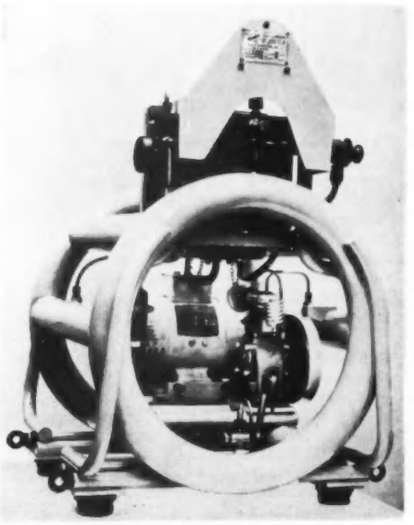
Tubular Receiver

Originally developed for Service needs, an air compressor built mainly of non-magnetic materials has been produced by the Hymatic Engineering Company, Limited, Redditch. It is shown in the illustration below.

The compressor unit is a variation of the S50 unit, originally built for aircraft use, and has a handling capacity of 0·5 cub. ft. per min. of free air when working at its normal operating pressure of 350 lb. per sq. in. A two-stage stepped piston is employed. The spokes of the driving pulley are designed to act as fan blades, and cool both the cylinder barrel and the intercooler. Parts such as the crankshaft roller bearings and the white-metal bottom end bearings have been designed to withstand forces occurring under high load conditions. Splash lubrication is used.

The receiver has a capacity of 1 cub. ft. and is unusual in its design as it is made of welded Tungum tubing. The form in which this has been shaped (as may be seen from the illustration) both reduces the overall size and protects the complete unit. The shape also provides a large cooling area allowing a large percentage of the moisture carried over to condense; this can then be withdrawn through two drain taps. Further cleansing is carried out by an oil and water trap in the delivery line. Tungum has also been used for the compressor crankcase and the switch box; other parts are of aluminium alloy. The set is mounted on anti-vibration supports.

A ½ h.p. motor is used to drive the compressor and the control can be either manual or automatic. In the latter case a pressure-operated switch is used to stop and start the motor. A relief valve and pressure gauge are also fitted.



The air receiver, made of non-magnetic Tungum tube, forms a guard for the complete compressor unit.

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VACUUM FORMING

The British Plastics Federation has now established a Vacuum Forming sub-section of its Fabricators Group to cater for the interests of those who are engaged in this growing branch of the industry.

This step follows the recommendations of an informal meeting held on May 15 last, to which all companies interested in vacuum forming were invited.

Book Reviews

MODERNITY THE ESSENTIAL THING

Design and Construction of Steel Merchant Ships. Edited by DAVID ARNOTT. *The Society of Naval Architects and Marine Engineers, 74 Trinity-place, New York 6, N.Y., U.S.A.* (14 dols.)

The Society of Naval Architects and Marine Engineers have an established reputation as publishers of excellent text-books. The *Principles of Naval Architecture*, published in 1939, and *Marine Engineering*, first issued in 1942, proved to be best sellers and have already been reprinted many times. Another book, *Shipbuilding Business in the United States*, is a unique publication which has no parallel in shipbuilding literature. The present volume is a worthy addition to the series and will no doubt enjoy an equal popularity in professional circles.

The book is the work of an editorial committee, and one can hardly envy their task of deciding not so much what should be included but what should be left out of the enormous material from which they had to make a selection. In the foreword, we are informed that the purpose of the book is " to assist students and others entering the field of shipbuilding towards a knowledge of how merchant ships are designed and constructed and to provide them with a good background for more advanced study." The editor and authors have achieved this purpose admirably.

It would be difficult to find serious faults but the book gives some scope for argument on the manner of presentation of the various subjects discussed. When explaining the fundamentals of design to a student, it is generally recognised as good teaching not only to instruct him on basic principles and their application but also, where possible, to warn him against bad or difficult features of design. Thus, it would be instructive to a student if he were told that turret and trunk ships, attractive as they were for many reasons, were eventually abandoned because of their notoriously bad stability at all but small angles of heel; that large deep tanks amidships are undesirable from a structural strength point of view; that calculations of stresses in stays are handicapped by uncertainty about the E-values of wire ropes, etc. These are but a few examples, and there are several other problems which could be treated in a similar way with advantage.

Some of the best chapters deal with the structural design of a hull. The great advances achieved in this field in post-war years, mainly due to the extensive application of welding, are ably and clearly portrayed. The section on longitudinal framing is, however, somewhat brief in view of the importance of this method of construction to-day. It is well known that longitudinal framing should be effectively continuous through transverse bulkheads, but this is not very easily achieved in practice. The author rightly emphasises the need for continuity but offers no solution as to how it should be met. The persistent and patient persuasion of the classification societies, exercised over a number of years, is beginning at last to bear fruit: longitudinal framing in conjunction with welded construction is gradually taking a dominant place in modern ships in preference to transverse framing. In the United Kingdom at least, it takes the form of a combined system in which longitudinal framing is used in the double bottom and deck, with transverse frames at the sides. The riveted version of this system of construction is, in fact, shown in Fig. 11, on page 78, but it is hidden there among other ships, which, to-day, are only of historical interest. The reader might have been better informed if a similar midship section, showing a combined system in a welded ship, had been given in the passage on longitudinal framing, and if he had been told that this would be a likely cargo ship of the future.

There is another point on the subject of emphasis. The large drawings of ships of the past in chapter 3 (*a*) seem to occupy space out of proportion to their present-day importance. If space were saved here it could be used, for instance, to show examples of panting arrangements in the forward part of the ship, and to give a little more information on the important problem of structural interaction between the main hull girder and a long deckhouse or superstructure. This is one of the features of ship design which gave a great deal of trouble in the past. It is now a subject of intensive research by many maritime nations, and some encouraging results have already been obtained. It is true that most of these results were not generally known at the time of publication of this book, but a reference to the theoretical work of Crawford and Bleich, and a drawing showing the distribution of longitudinal stress in hull and superstructure, obtained from the tests on the President Wilson, would have struck a hopeful note by showing that the problem was being tackled and that a solution could not be far away.

The general arrangement of the book follows the well-established pattern adopted in their previous publications. As stated, the contents are divided into a number of chapters, each written by a separate author, and there is a comprehensive bibliography, mainly of American sources, following most of the chapters. The first illustration in the book is of the latest American liner, the S.S. United States, and the proud sub-title informs us that it is the fastest merchant ship in the world. The last sentence of the first chapter declares: " the fullest advantage should be taken of new worthwhile technical developments so that the ship will be up to date, and *if possible ahead of her time*, with due regard to the competitive requirements of the trade." The photograph and the sentence quoted—the italics are the reviewer's—symbolise the essential quality of the book: its modernity. It is undoubtedly one of the most up-to-date books available on ship construction. It deals exclusively with modern steel merchant ships; there are a few examples of ships of the past, such as the Great Eastern, and a few obsolete tankers and trunk ships, but that is because they represent milestones in shipbuilding progress and help to put modern developments in a proper historical perspective.

An introduction to the subject is given by the editor of the book, Mr. David Arnott, former vice-president and chief surveyor of the American Bureau of Shipping, and this is followed by a chapter on basic design, which contains an excellent outline of design procedure supplemented by detailed particulars of seven typical modern ships. Some chapters give unusually extensive information which it would be difficult to find elsewhere in an equally enlightening form, such as design of accommodation, cargo handling arrangements, hull piping systems and air conditioning. The main part of the book deals with the steel structure of ships, and there are excellent sections on structural strength, hull materials, methods of joining structural parts (with the emphasis on welding), and design of structural members. There are also chapters dealing with details and fittings; anchor, mooring and towing arrangements, and steering; life-saving equipment and aids to navigation; shipyard practice; and hull preservation and maintenance. A useful glossary of hull terms and a detailed index complete the book.

NEW BOOKS

Some of the books noticed here are selected for extended review in ENGINEERING.

Electrical Principles. By H. COTTON. *Cleaver-Hume Press, Limited, 31 Wright's-lane, Kensington, London, W.8.* (12*s.*)

A sound grasp of fundamentals will be the need of both the technologist and the physicist during the next decade. The logical approach to electricity is through atomic structure. The M.K.S. system can now be used from the beginning. A text-book should pleasantly make all these essentials clear, quite independently of lectures. This book has been based on these assumptions. It provides within this framework for first and second year work in technical colleges and covers the needs of those beginners who have to be taught the theory of electricity and magnetism, the principles of direct-current machines and the essentials of alternating currents. Certain subjects, such as the electrophorous, have been omitted, while others, such as conduction through gases and thermo-electricity, which do not normally find their way into elementary text-books, have been included.

Garcke's Manual of Electricity Supply, 1955-56. Compiled under the supervision of FREDERICK C. GARRETT. *Electrical Press, Limited, 19/20 Noel-street, London, W.1.* (77*s.* 6*d.*)

This well-known statistical record of the British Electricity Supply and Allied Manufacturing Industries follows the familiar pattern. It includes a general survey of electricity supply in Great Britain between 1948 and 1955, which is based on the annual reports of the Central Electricity Authority and the Area Boards as well as upon those of the North of Scotland Hydro-Electric Board and the South of Scotland Electricity Board. The Herbert Report and nuclear power developments are also dealt with.

As in previous editions, details are given of the organisation of the Central Authority and its Divisions, with data regarding generating station equipment and operation. Similar information regarding the Area Boards is provided and, finally, there is a directory of executive personnel.

The Festiniog Railway. Vol. I. 1800-1889. By J. I. C. BOYD. *The Oakwood Press, Bucklands, Tandridge-lane, Lingfield, Surrey.* (24*s.* 6*d.*)

This book is of some topical interest, since the Festiniog Railway is now enjoying a new lease of life as a passenger-carrying service. It is a narrow gauge (2 ft.) system, operating in the hills of North West Wales and was the subject of an article in ENGINEERING for June 1, 1956.

Variable Resistors. By G. W. A. DUMMER. *Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2.* (30*s.*)

This is the second volume of a series on radio and electronic components, the first of which dealt with fixed resistors. It has been written from the point of view of the user, to enable him to choose the best component for his particular requirement and to understand its fundamental characteristics. Comparison charts enable the characteristics of many types of similar components to be readily seen.

Other volumes will cover fixed and variable capacitors in a similar manner.

Reliability Factors for Ground Electronic Equipment. Edited by KEITH HENNEY. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (7.50 dols.): and *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (56*s.* 6*d.*)

The reliability of electronic equipment is becoming more and more of a problem as more automatic apparatus is being brought into use. Particularly in wartime, it is essential that instruments shall not go wrong at an unfortunate moment. This volume discusses the numerous reasons why military electronic equipment does not have the necessary reliability, and ways by which greater reliability can be obtained in future equipment are pointed out. Chapters deal with such items as the concept of reliability, causes of unreliability, mathematical and statistical approach, environmental and human factors, and general maintenance.

Diesel Operator's Guide. By C. MORGAN JONES. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (6.50 dols.); and *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (49*s.*)

The book covers practical facts for day-to-day maintenance of Diesel engines, whether of the two or four-stroke cycle, but all of American origin. The matter is presented in a style mainly suitable for maintenance and semi-skilled men, and deals with the various components of the engine in separate chapters. Typical maintenance schedules are included at the end.

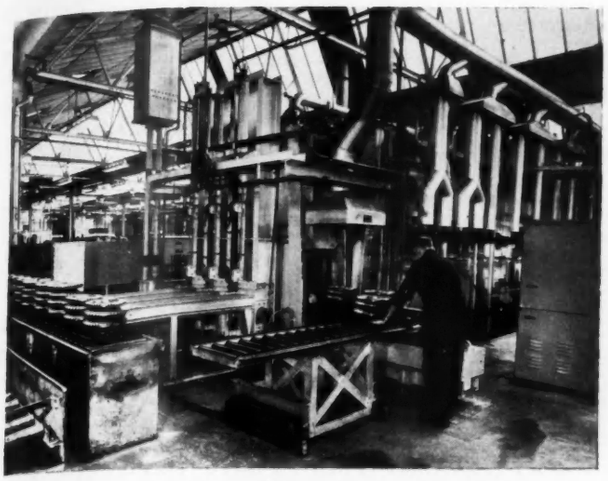

Fig. 1 Work carried on heat-resisting trays is loaded into the vestibule or gas-lock of the furnace. The operating cycle is then automatic.

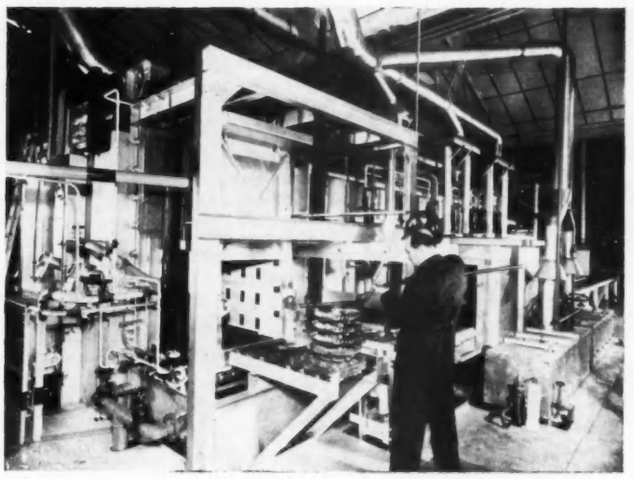

Fig. 2 At the discharge end, the work can be either quenched automatically or removed by hand for press-quenching.

CASE-HARDENING AUTOMOBILE GEARS

CONTINUOUS GAS CARBURISING FURNACE

Gas carburising is now widely practised in place of the older pack process, and the tendency in recent years has been to make the gas process continuous wherever possible. For handling large outputs of similar components in a limited metallurgical specification range the continuous process is ideal. With a suitably-designed furnace it is possible to have a high degree of mechanisation combined with accurate automatic metallurgical control which is also flexible to suit production requirements. Such a furnace has been designed and built by Birlec, Limited, Tyburn-road, Erdington, Birmingham, 24, for the E.N.V. Engineering Company, Limited, Hythe-road, Willesden, London, N.W.10.

40 TONS OF GEARS A WEEK

The furnace has a rated capacity of 600 lb. of work an hour, and it can handle something over 40 tons in a week of 168 hours. If only a medium case depth is required this output can be exceeded. All the work of loading, carburising, quenching, washing and unloading of the components being treated, which are various automobile gears, is done within a floor space of approximately 49 ft. by 25 ft., the length of the furnace heating chamber being approximately 31 ft.

Gears are transported through the furnace on heat-resisting grid-type trays 18 in. square, moving on three parallel tracks. Each tray carries up to 150 lb. of gears. Heating is by gas-fired radiant tubes, arranged transversely above and below the conveyor tracks. At full output the gas consumption is in the region of 4,200 cub. ft. an hour. The carburising atmosphere is provided by Birlec endothermic gas generators, working with propane, for which there are two storage tanks. Propane supplies are delivered by road tank wagons. There are three generators, one serving the furnace chamber, one providing gas for the lock chambers or vestibules at each end of the furnace, and one being held in reserve. The two generators in use at any time require about 160 cub. ft. of propane an hour for an output of atmosphere gas of about 1,600 cub. ft. an hour for the furnace, and a periodic on-off supply of 1,000 cub. ft. an hour for purging the lock chambers.

TWO OR THREE-MAN OPERATION

The high degree of mechanisation, coupled with automatic control, makes it possible for the furnace to be run normally with only two operators. Provision is made for extraction of individual work pieces by hand for press quenching when necessary, instead of direct quenching from the discharge vestibule, and when the furnace is being used in conjunction with a press a third operator is desirable. In both cases the work-carrier trays are circulated continuously through the furnace and along the unloading-loading track. The work is cleaned in a washing machine before loading, and the operators also attend to this and to the tempering which follows case-hardening.

Movement of the work trays through the furnace is effected by means of hydraulic cylinders and rams supplied with fluid from a central pump unit, and controlled electrically through a sequencing circuit. A non-inflammable hydraulic fluid is used to obviate fire risks.

PUSH-BUTTON CONTROLLED FURNACE CYCLE

The furnace is normally charged after every third cycle, that is, after each track has moved once. To charge gears for treatment, loaded trays are moved by hand from the roller track which brings them from the loading and unloading point, on to a transfer trolley. The vestibule door is then opened, the loading trolley extracted mechanically, and the trays moved on to it by hand. The loading trolley is then returned to the vestibule, and the door is closed. The loading of new work is shown in Fig. 1.

When the loading trolley is charged and in position in the vestibule the furnace cycle can be started. This is done by the operator using a push-button in accordance with a bell and light signal given by an automatic timer at the appropriate time interval. In practice there is a minimum track cycle time of about 27 minutes, which corresponds to about 9 hours total time for each tray in the furnace. Operation of the push-button starts an automatic sequence, and the tray is charged into the furnace, while one tray at the opposite end is discharged. There is a separate timer for each track, and all three tracks can be operated independently according to the metallurgical conditions required.

The furnace cycle of five stages is:

(1) The inner door of the vestibule opens and the new tray is pushed into the furnace chamber to move the whole line of trays one tray length forward. At the discharge end the leading-tray is lined up against a stop by an extractor mechanism.

(2) The quench elevator rises, the inner discharge door opens, and the leading tray is pushed sideways into the discharge vestibule. The inner door closes.

(3) The quench elevator descends and immerses the tray of work in a fast-moving vertical oil stream for a pre-set time.

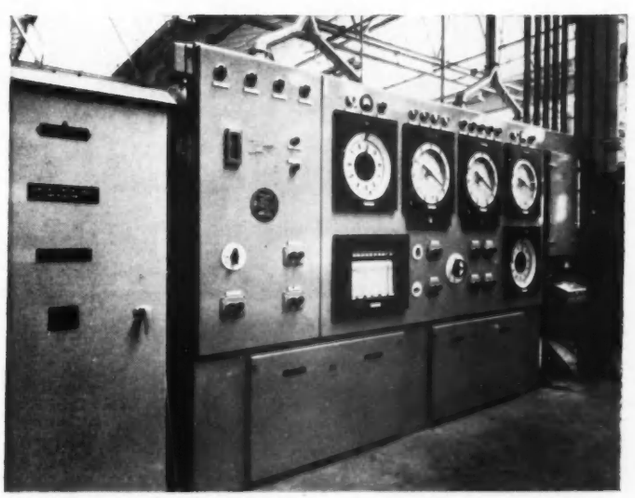

Fig. 3 All controls, instruments and automatic controllers are grouped on a central control panel.

(4) The tray moves sideways in the quench tank and is elevated to its discharge position.

(5) The tray is pushed on to the discharge track and through the washing machine to the unloading position. Unloaded trays continue along the track for re-loading.

A switch at the discharge end allows the sequence to be interrupted when the tray is in the vestibule. A signal is given automatically and the outer door can then be raised to extract the work for press quenching. The tray is returned, and the closing of the door brings the automatic cycle once more into operation. Removal of components for press-quenching is shown in Fig. 2.

Purge gas is supplied to each vestibule automatically as soon as the outer door is closed; this gas is fed in for a pre-determined period to sweep out air and burnt gas.

The furnace chamber has four zones, each subject to independent automatic control. The first zone raises the temperature of the load to the pre-determined value for carburising, the second and third maintain it for a period determined by the rate at which the trays are moved along the tracks, and the third brings the load to the temperature required for correct quenching conditions. Zones 2 and 3 are equipped with gas-circulating fans to ensure uniform carburisation all over the work-surfaces, and zone 4 is arranged for either heating or cooling as required.

All the controls, instruments and automatic controllers are grouped on the central control panel shown in Fig. 3.

MOVEMENT OF WAGONS AT A COAL TIPPLING PLANT

CENTRALISED CONTROL WITH ONE OPERATOR

All types of four-wheeled wagon used on British Railways, including the recently-introduced 24½ ton vehicle, can be handled by the wagon-marshalling equipment developed by the Fraser and Chalmers Engineering Works, Erith, of the General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2. The equipment has been designed to suit the requirements of the railway system in Britain, but it can be adapted to suit foreign gauges and other types of rolling stock. Only one operator is needed for both the marshalling equipment and the tippler, the controls for both being grouped at a centralised control point and interlocked to prevent wrong-sequence operation. Locomotive power is only necessary to bring a train of full wagons (up to 16 in number), to the "full" siding, and to remove the discharged wagons from the "empties" siding. All movement between these two points is effected by the marshalling equipment.

THREE HAULAGE UNITS

The equipment, the general arrangement of which is shown below, comprises three flanged-wheeled winch-hauled bogies which run on rail track and move the wagons from the "full" siding to the tipper, over the tippler, and into the "empties" siding, respectively. These bogies, which can be referred to as units, A, B and C, are partly push-button controlled and partly sequence controlled by automatic means.

In operation, unit A, which runs on an auxiliary track between the main wagon rails, advances the entire train of full wagons by one wagon length. Unit B, which is on rail track alongside the main rails, engages the leading wagon of the train and propels it to the tippler; this displaces any empty wagon which is already there. The last unit, C, which runs on rails of the same type as unit A, moves forward the discharged empty wagon and any others in front of it to the "empties" siding. Units A and C each have a centrally-pivoted swinging arm carrying anti-friction mounted driving and support rollers at each end. When this arm has its axis at right angles to the centre-line of the rail track the driving rollers engage the wagon wheels between the wheel flange and the rail head, and the support rollers run on the main rail track. The rollers are clear of the inside faces of the wagon wheels when the arm is in its retracted position, and the wagons can pass over it freely. Unit B also has a swinging arm, but as the unit runs on rails alongside the main track, the arm extends from the side, and engages one wheel only with its driving roller.

SETTING THE DRIVING ARM

To start the operating cycle, unit A is run to the end of its travel remote from the tippler, the swinging arm having first been retracted automatically by means of a track stop. The train of wagons is then brought by locomotive to the "full" siding; all the wagons will pass over the unit A as the arm is retracted. Unit A is then started on its inwards journey, and at a set point a rail stop moves the swinging arm automatically to its traction position. The unit is then advanced until the driving rollers are against the wheels of the rearmost wagon, and the wagons are uncoupled. The operator now advances the complete train at a speed of 12 ft. per minute by means of unit A until the rear wheels of the leading wagon reach a control point, when the train stops automatically.

The train is now ready for the discharging operation to commence, and unit B is at the outer limit of its travel at the control point. A special form of limit switch and an automatic safety wagon stop are located at the control point, where the wagons are transferred from unit A to unit B. To start discharging, the operator causes unit B to move towards the tippler, its swinging arm being set in the operating position and the wagon stop lowered by means of cams on the track. Unit B then engages the rear wheel of the wagon and propels it towards the tippler, the wagon stop being re-set automatically when the rear wheels of the wagon have passed over the control point. The wagon is propelled at 60 ft. per minute to the tippler, and stopped as required by the operator.

AUTOMATIC RE-STARTING

While unit B is propelling the wagon on to the tippler, a limit switch starts unit A automatically. This moves the entire train forward by the length of the leading wagon. Unit B is then returned to its starting position at the control point, and the wagon is discharged by means of the tippler, under the control of the operator.

The empty wagon discharged from the tippler by the oncoming full one comes to rest in a track depression in the "empties" siding. From this position it is moved forward by unit C, which travels at 40 ft. per minute. This unit moves to its full forward limit of travel and returns automatically, the swinging arm being set and retracted by track cams. The sequence of operation continues until all the wagons from the "full" siding have been discharged and passed to the "empties" siding.

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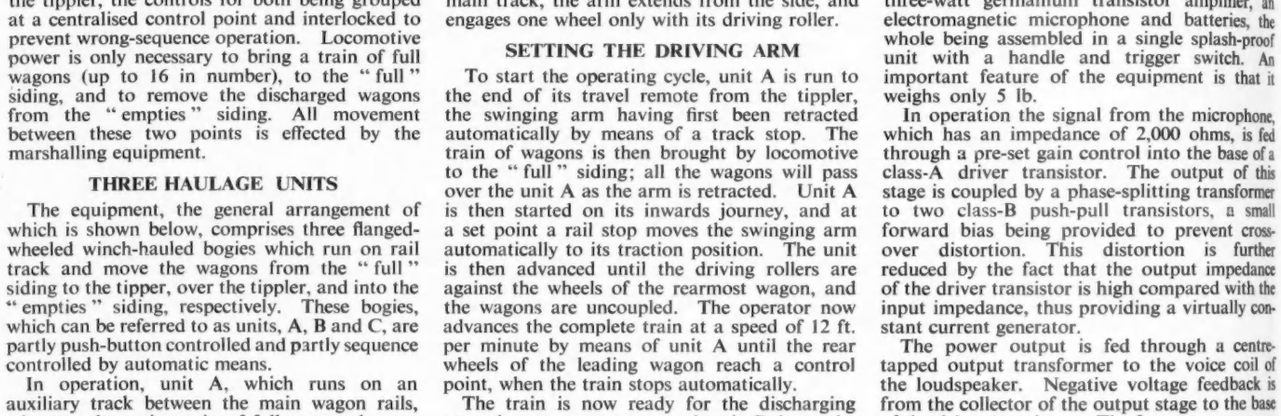
AN ELECTRONIC MEGAPHONE

An electronic megaphone, known as the Transhailer, in which transistors are used instead of valves, has been introduced by Pye, Limited, Cambridge. It is intended for use in talking across distances or against background noises, and consists of a folded-horn loudspeaker, a three-watt germanium transistor amplifier, an electromagnetic microphone and batteries, the whole being assembled in a single splash-proof unit with a handle and trigger switch. An important feature of the equipment is that it weighs only 5 lb.

In operation the signal from the microphone, which has an impedance of 2,000 ohms, is fed through a pre-set gain control into the base of a class-A driver transistor. The output of this stage is coupled by a phase-splitting transformer to two class-B push-pull transistors, a small forward bias being provided to prevent cross-over distortion. This distortion is further reduced by the fact that the output impedance of the driver transistor is high compared with the input impedance, thus providing a virtually constant current generator.

The power output is fed through a centre-tapped output transformer to the voice coil of the loudspeaker. Negative voltage feedback is from the collector of the output stage to the base of the driver transistor. The frequency response is flat within 3 decibels in the range between 200 and 4,000 cycles. Its average consumption is 120 milliamperes, giving a battery life of 12 hours on a duty cycle of 20 seconds on, 20 seconds off.

The Transhailer was installed on the "Moyana" which recently won the England to Lisbon race and was instrumental in the rescue of the crew during the subsequent gale.



Railway wagons are discharged by the marshalling equipment and tippler shown in this diagrammatic drawing. The complete installation is under the control of a single operator.

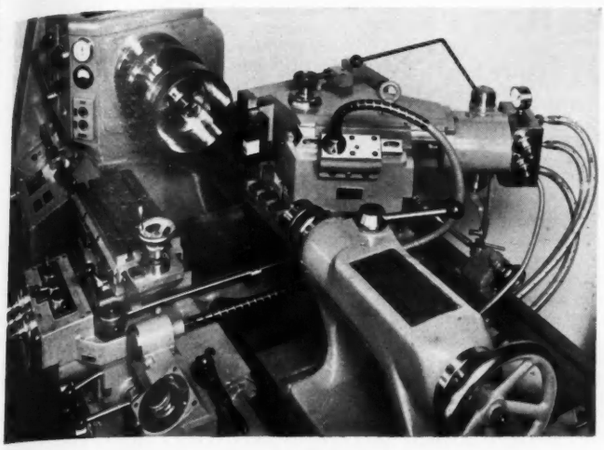


Fig. 1 By automatically varying the spindle speed according to the work diameter, the optimum cutting speed for the material can be maintained.

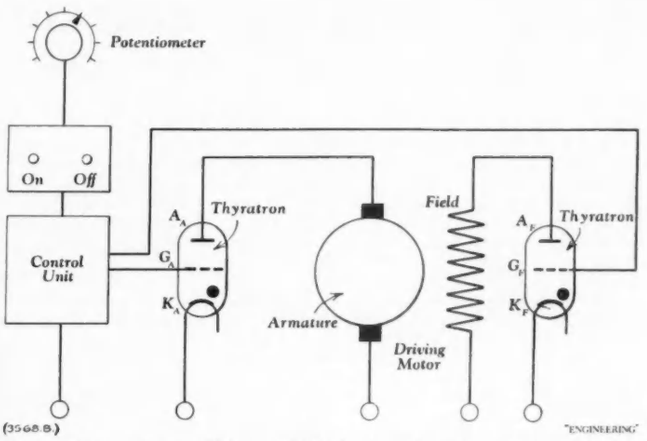


Fig. 2 The motor speed is controlled by two thyratrons, whose operation is governed by potentiometers, one of which is actuated by the movement of the cross slide.

CUTTING AT CONSTANT SPEED

AUTOMATIC DEVICE FOR LATHES CONTROLLED BY WORK DIAMETER

In all machining there is an optimum feed and speed to obtain the best finish on the material. This probably applies to lathe work most when large faces have to be turned. Unless the spindle speed is varied as the cut progresses, the quality of finish will also vary from the edge to the centre, and, in any case, where the steps in speed change are large, a compromise must be found between the two limits. Moreover, unless the optimum cutting speed is maintained, tool life will be reduced as well as a poorer finish being obtained.

A lathe known as the " Electromatic," designed to meet this requirement, has recently been put on the market by Max Müller-Brinker Maschinenfabrik of Hannover, the agents for whom in this country are K. S. Paul Limited, Great Western Trading Estate, Park Royal-road, London, N.W.10. This lathe not only has an infinitely variable spindle speed over a range of 7 to 1, but has an attachment which varies this speed according to the diameter of the work piece. In this way, a truly constant cutting speed can be maintained, giving considerable economy in tool life, better surface finish, and decreased machining time. The lathes are multi-purpose machines equipped for copy-turning. The headstock and saddle of one model are shown in the illustration, Fig. 1.

The spindle is driven by a direct-current motor which has controls in both the armature and field circuits. The main circuits are shown in the diagram (Fig. 2). The speed range, which is from 430 r.p.m. to 3,000 r.p.m., is divided into two parts from the point of view of control. The first, from 430 to 1,000 r.p.m., is governed by the voltage applied to the armature, and the second, from 1,000 to 3,000 r.p.m. by varying the field current. In each case the operation is regulated by a thyratron, which has an alternating supply on the anode, that to the grid being 90 deg. out of phase. Superimposed on the grid is a direct-current potential, which can be varied by a potentiometer and controls the firing of the thyratron, and therefore the direct-current output to the motor. By adjustment of this potentiometer (which is mounted on the headstock) the spindle speed can be set to suit the the work in hand.

When automatic speed regulation is required, the potentiometer mentioned above is switched out of circuit, and its functions are taken over by two others, one also on the headstock, the second on the saddle apron. The former is pre-set by hand to give the optimum spindle speed under the initial conditions, and the variations are controlled by the latter. This is done by linking the cross slide to the potentiometer spindle so that movement in or out (corresponding to a change in diameter of the workpiece) is transferred to the potentiometer, which in turn controls the motor speed through the thyratrons, as described above. When copy-turning, the movement of the copying slide is added to that of the cross slide and the combined effect used to adjust the potentiometer.

Experiments have shown that, by maintaining the cutting speed constant at its optimum value, the tool was capable of removing about 65 per cent. more stock before becoming blunted, as it would have done had only a constant spindle speed been maintained. In addition, a uniform surface finish could be obtained, even over a large-diameter facing. Several models of these lathes are made, with capacities varying from $6\frac{3}{8}$ in. diameter (over carriage) by 30 in. between centres, up to $17\frac{3}{4}$ in. diameter by 100 in. between centres. A complete range of accessories, for oval turning and the like, is also available.

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PRECISION CASTING IN ALLOY STEELS

Several years ago, when tungsten was in short supply, the B.S.A. Tools Research Centre developed a process for casting milling cutters in alloy steel containing only 4 per cent. tungsten which proved to be very satisfactory and economical. The possibilities of much wider applications for precision castings in alloy steels led to the formation, in 1954, of Precision Alloy Castings (Birmingham), Limited, Mackadown Lane, Kitts Green, Birmingham, 33. After two years, the company are now producing castings to over 40 standard specifications, as well as to customers' special requirements. They are approved by the Aeronautical Inspection Directorate and the Department of Inspectorate of Armaments. For intricate parts such as cutting tools, extrusion dies, swaging dies, etc., and for prototype work, the process is quick and economical. Certain types of cast dies have proved to have a longer life than the corresponding forged dies, on account of their absence of directional properties.

The sand moulds in which the alloys are cast are coated and sprayed with a special solution and baked overnight. The casting furnaces, designed and constructed by Precision Alloy Castings, are of the indirect arc type and have a capacity of 40 lb. which can, in certain circumstances, be increased to 80 lb. The refractory linings, of Magnesite chrome, which are not removable, have a life of about 75 to 80 melts. Before adding the alloying constituents, a quick carbon check of the melt is taken in a swarf-sampling device; and often it is possible, should the carbon content not prove to be according to specification for the particular job, to divert the melt to another job for which it is suitable.

The molten alloy is poured direct from furnace to mould. Subsequently the casting is fully annealed and any necessary rough machining is carried out. The foundry is not equipped for finish machining. To ensure that the castings are free from flaws, gamma radiography is employed using a Cobalt 60 source.

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REMOTE CONTROL OF POWER PLANT BY RADIO LINK

A power plant, which will be operated by remote control through a radio link from a point 12 miles away, is to be equipped by the English Electric Company, Limited, London.

The station is to be built on the Warragamba River as part of a scheme for supplying water to Sydney, the surplus water being used for generating electricity. It will be operated in conjunction with the steam stations in the main network of New South Wales either to carry peak or base loads. The equipment will consist of a 69,000 h.p. reaction turbine coupled to a 62·5 MVA alternator the output of which will be stepped up to 132 kV.

A scalping cutter 6 in. in diameter and 20 in. long cast by Precision Alloy Castings (Birmingham), Ltd.

SPACE-SAVING SWITCHGEAR

OUTDOOR METALCLAD 33 KV INSTALLATION AT TAFF BANK

At the Taff Bank substation (Cardiff) of the South Wales Electricity Board, which was officially opened on July 27 by Alderman D. T. Williams, Lord Mayor of Cardiff, use has been made of metalclad, air insulated switchgear, manufactured by South Wales Switchgear Limited, Blackwood, Monmouthshire, to handle the 33 kV supply. One of the great advantages claimed for this equipment is the saving in ground area; the seven unit board only occupying a space of 900 sq. ft., while other types of outdoor switchgear may require ten times this amount. In a restricted built-up district, or in very hilly country, this may be of considerable importance.

Taff Bank forms part of a 33 kV system that is under construction, and is fed from Roath power station through Sandon-street sub-station. Later, there will be a supply from Cardiff West grid sub-station which is also to have similar metalclad switchgear. The board consists of seven panels with a bus section; three of the breakers control the supply to distribution transformers and another breaker the supply to Currans Steel sub-station at 33 kV. The finished sub-station is shown in Fig. 2.

Fig. 1 All three phases of the vertically isolated breaker are contained in one tank. Adjustments can be made without withdrawing the breaker from its chamber.

The design is based in general on the American package type switchgear but with the important difference that the American model has a three-tank circuit-breaker, whereas the South Wales type has one tank for all three phases. All parts are jig built in the shops and are erected there prior to being transported to site, with the result that the Taff Bank substation was constructed complete in three weeks ready for cabling up. Drawing-office work is also considerably reduced. One of the main breakers in the isolated position with the tank lowered is illustrated in Fig. 1.

As will be seen, vertical isolation has been employed with automatic shutter gear for sealing the entrances to the busbar chamber. The busbar chamber itself is air insulated, and so are the circuit-breaker plugging members. The shutter gear has a positive drive from the side bar of the circuit-breaker as the latter is raised or lowered in the chamber and a motor-operated mechanism is provided for carrying out the raising and lowering.

The breaker is raised and lowered on four lead screws, which are driven by worm and wheel gear from a common shaft. An interlocked coupling on the end of the shaft transmits the drive either from the motor unit or, if necessary, from a handle. The breaker is lowered on to a small four-wheel trolley on which it can be withdrawn from the chamber. It is possible to inspect and even change the contacts without removing the breaker completely from the unit, thus keeping it under cover during inclement weather conditions.

The single tank in which the circuit-breaker is housed is of fabricated steel plate and is lined with insulating material. Inter-phase barriers of the same material are used; and a prismatic oil gauge is fitted for the visual indication of the level of the oil.

The top plate is a silicon aluminium alloy casting and incorporates pebble filled gas vents. The combined main and arcing contacts are of the self-aligning "rose" high pressure line-contact type for minimum burning during short-circuit operation. Each is mounted inside an arc control tube of synthetic resin bonded fabric. The arc control operates on the side-cross jet principle and positive extinction is effected. Ring type current transformers are fitted on the bushings as required, and may be accommodated on either or both sides of the circuit-breaker. Three types of operation are available, either by a hand wound spring, a motor wound spring as at Taff Bank, or a solenoid closing mechanism; these are interchangeable.

Voltage transformers are fitted at the back of the circuit-breaker and connect with terminals in the outgoing cable side. The impulse withstand of the equipment is 200 kV, and insulation creepage paths in the fixed portion are comparable with 44 kV outdoor practice.

The switchgear has been successfully tested on short-circuit for loads up to 1,000 MVA rating, and also on a five-second through fault. The protective gear on the control panel for the switchboard was supplied by Metropolitan-Vickers Limited, and includes Translay feeder protection.

Fig. 2 Employing air insulation, a seven panel 33 kV switchboard requires only 900 sq. ft. of ground space.

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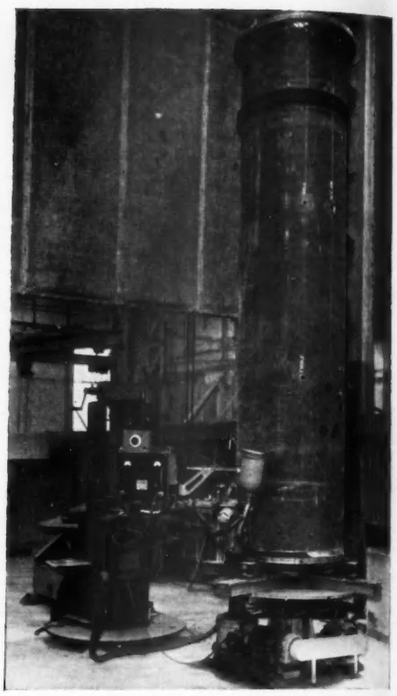

The tube plates of condensers and evaporators can be welded to the shells on this automatic submerged-arc equipment.

WELDING IN THE REFRIGERATION INDUSTRY

Operating Time Reduced

The accompanying illustration shows automatic welding equipment, which has been designed by Quasi-Arc Limited, Bilston, Staffordshire, and has been installed in the works of Messrs. J. and E. Hall, Limited, Dartford, for welding stainless-clad mild-steel tube plates to mild-steel evaporator and condenser shells. It comprises a welding head positioner, which carries a standard D.S. Unionmelt head. This head, which can be swung to either station for welding, has a double speed gearbox rocker attachment and scratch starting. An 8 ton rotator and 10 cwt. manipulator, which is visible in the background of the illustration, also forms part of the equipment. Current is supplied from a 1,200 ampere power pack.

A guide wheel attachment which is maintained in position during welding ensures that the head is accurately guided round the periphery of the shell. The use of submerged arc welding in this way enables the time required for welding each tube plate to be reduced from 6½ hours with hand welding to 4 hours. Distortion is also minimised and only hand grinding of the mating dished end cover flange is necessary so that it will fit the evaporator tube plate.

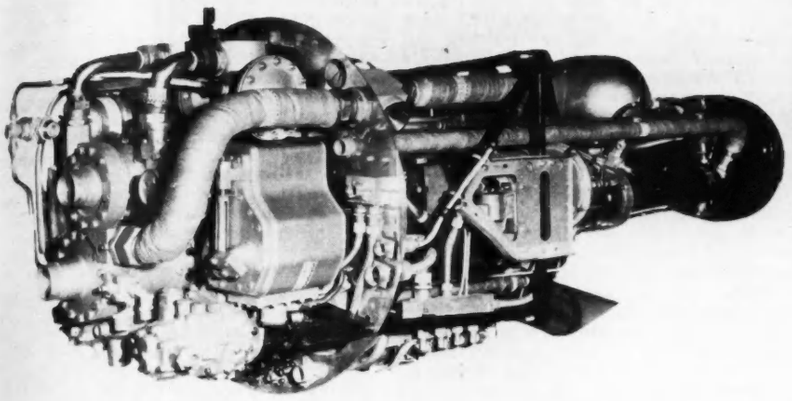

Fig. 1

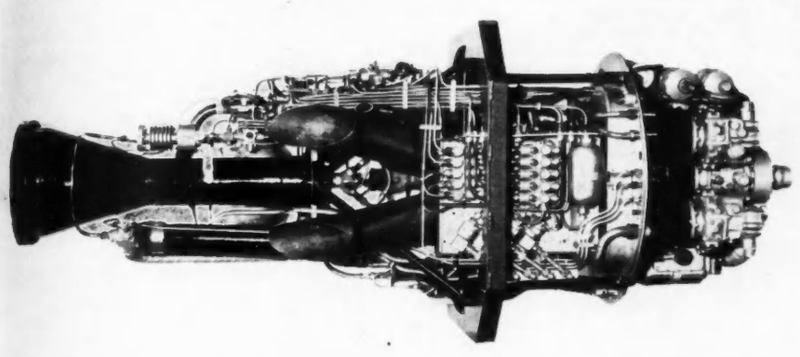

Fig. 2

Figs. 1 and 2 In the " Screamer " a single turbine drives liquid-oxygen, kerosine and water pumps which supply the main combustion chamber. Power for the turbine is supplied from a gas generator in which fuel and liquid oxygen are burnt and used to evaporate injected water. Fig. 2, depicting the underside of the engine, shows part of the engine control system and its associated network of nitrogen pipelines for operating valves.

"SCREAMER" ROCKET FOR PILOTED AIRCRAFT

TRI-PROPELLANT VARIABLE-THRUST UNIT

Among the more unorthodox power plants to be seen in the static exhibition of the Society of British Aircraft Constructors annual display at Farnborough, Hampshire, will be the 8,000 lb. thrust " Screamer " rocket motor developed by Armstrong Siddeley Motors Limited, Coventry, Warwickshire. The " Screamer," the security classification, of which has recently been lifted completely, has been designed as a self-contained power plant for installation in a piloted aircraft, either as part of a " mixed power plant " in conjunction with turbojets, or as the sole means of propulsion. The thrust can be controlled by single-lever operation over a range of 1,000 lb. to 8,000 lb.; the engine is designed for operation over a range of altitude and is suitable for inverted flight. An overhaul life of at least 25 hours has been one of the main objectives of development. It employs liquid oxygen, kerosine, and water as propellants—the main purpose of the water supply being to provide steam for a turbine driving the propellant pumps. It also serves to cool the main combustion chamber and dilute the combustion gases.

The " Screamer " has, in fact, never been flight-tested, although it completed its pre-flight clearance tests to half-thrust in December last. It has successfully run for a total of three hours at full thrust, and had actually been installed in a Meteor flying test-bed when the Ministry of Supply cancelled the contract for the engine. The reason for the cancellation was that official policy now is to concentrate on hydrogen peroxide rocket motors for piloted aircraft, in which the use of liquid oxygen has certain disadvantages—it requires a larger stowage space, and evaporation losses are inevitable while the aircraft is standing. The control of a tri-propellant motor such as the " Screamer " is, moreover, inevitably more complex in an installation where the ability to start the engine in flight safely, without hazard from the accumulation of unburnt propellants, is a primary consideration.

On the other hand, supplies of high-test peroxide are costly and less easily available than are kerosine and oxygen; and the specific impulse obtainable from burning kerosine with oxygen is greater. In time of war and short supplies, it might arise that the liquid oxygen rocket would regain favour, particularly in long-range high-altitude missile applications, where the elaborate safeguards required for piloted flight are not necessary.

In the " Screamer " a single turbine drives, through a gearbox, the liquid oxygen, kerosine and water pumps supplying the main combustion chamber, which is unusual in having no convergent-divergent nozzle but only a divergent expansion cone. The turbine also drives two Dowty Vardel hydraulic pumps for the aircraft services. Power for the turbine is supplied from a gas generator in which fuel and liquid oxygen are burnt and used to evaporate injected water, the resultant gas mixture (mainly superheated steam) being fed to the turbine. The turbine exhausts through twin pipes below the engine.

Referring to Fig. 1, which shows the " Screamer " in the form in which it will appear at Farnborough, the gearbox and pump drives are on the forward side of the firewall (left side of illustration). The liquid oxygen pump is readily identified by its heavily lagged delivery pipe, and above it are the fuel pump and, almost concealed by the oxygen piping, the water pump. The two hydraulic pumps are at the bottom of the gearbox. Also mounted on the forward side of the firewall is the lubricating oil tank. Apart from the expansion nozzle, the main combustion chamber is concealed from view, as is also the gas generator on the starboard side towards the after end. The transverse tank aft of the engine mounting is a water starting tank, and the fore-and-aft cylindrical vessel below is the liquid-oxygen starting tank.

PILOT CONTROLS THRUST BY OXYGEN PRESSURE

The pilot's single control lever regulates the engine thrust by varying the pressure of liquid oxygen supplied by the pump to the gas generator. Pressure-balance valves ensure that the fuel and water pressures are automatically adjusted in relation to the oxygen pressure, both at the gas generator and at the main combustion chamber.

The cycle of operations on starting the engine follows a complex sequence designed to ensure safety, and a condensed account of these operations is given here. All the control valves are actuated by high-pressure nitrogen, supplied from storage bottles in the aircraft, and Fig. 2, showing the underside of the engine and the control system, gives some idea of the complexity of the system. The power plant includes three small starting tanks, for water, liquid oxygen, and kerosine, which serve to supply the gas generator before the pumps are running. Before firing, solenoid-controlled nitrogen-actuated suction valves in the pipelines from the main aircraft propellant tanks are opened, admitting propellants to the starting tanks and filling the main engine pipelines downstream of the tanks as far as the main stop valves.

When the pilot closes the engine starter switch, nitrogen at 450 lb. per sq. in. enters the three starting tanks, which are of the accumulator type, bag-type membranes separating the nitrogen from the liquid in the case of the fuel and water tanks, and a free piston serving the same purpose in the liquid-oxygen tank. All tanks are of stainless steel. At the same time nitrogen purges the lines to the gas generator. The pressure in the tanks causes liquid oxygen and fuel to be fed as far as the stop valves to the gas generator and its igniter, these valves still remaining closed. The pressure of the water injected into the gas chamber actuates valves admitting a small flow of fuel and oxygen to the igniter section of the gas generator. Here, they are fired by sparking plugs and the resultant pressure rise triggers the next stage of the cycle. If the pressure, however, fails to rise to its normal value within two seconds, the engine is automatically shut down.

If normal ignition has occurred, fuel and oxygen are admitted to the gas generator proper where they are ignited by the flame from the igniter. The combustion gases diluted by injected water set the turbine in motion and as

Fig. 3 Performance curves for the " Screamer."

the pumps begin to deliver the propellants are by-passed back to the main tanks. When the pumps have run up to speed, the water pressure directly downstream of the pump actuates the inlet valves to the igniter section of the main combustion chamber. When the combustion-chamber igniter lights up, the pressure of the burning gases triggers a switch which breaks the igniter plug circuit and opens the water valve to the combustion chamber cooling jacket. The cooling water pressure itself triggers the main oxygen inlet valve to the combustion chamber, which in turn triggers the fuel inlet valve. When the main chamber lights up, combustion pressure causes the starting tanks to be vented allowing them to re-charge with propellants for the next start, and the propellant pumps take over the task of feeding the gas generator. The whole sequence is completed within 3 to 4 seconds.

When the engine is shut down, the fuel and oxygen lines downstream of the stop valves are purged with nitrogen.

SUPERSONIC STEAM TURBINE

A steam turbine was adopted largely because a kerosine/oxygen gas turbine posed difficult high temperature problems; and the availability of a water supply simplified the task of cooling the combustion chambers—an essential provision with a flame temperature of some 3,200 deg. C.

The turbine fitted on the engine, which completed all the running at 8,000 lb. thrust, is a single-stage supersonic impulse type, 13 in. in diameter, comprising a 10 in. Rex 448 disc to which 43 blades of Nimonic 75 were attached by conventional fir-tree fixings. This was selected in preference to a Pelton-wheel type of turbine machined from a single steel disc, which proved less efficient and less acceptable to the workshops, but which was nevertheless fitted to the flight clearance engine. The turbine runs at about 20,000 r.p.m., delivering 350 h.p., and driving the propellant pumps through a gearbox at nearly 1-to-1 ratio. During the earlier tests on this turbine, a number of blade fatigue failures occurred after 3 to 5 hours running; the cause of which was found to lie primarily in the fact that three steam nozzles were used spaced 60 deg. apart, and a shock load was imposed on a blade each time it passed one of these nozzles. By replacing the three nozzles by a single one, a considerable improvement was obtained—but blade life was still below the standard aimed at, and just before the contract was cancelled Nimonic 80A blades were substituted for Nimonic 75.

IGNITER FUEL FED THROUGH SPARKING PLUGS

Standard igniters are used on both the main combustion chamber and the gas generator. They comprise an assembly of two specially designed sparking plugs, the central electrodes of which are hollow and form a passage through which kerosine is injected. A single jet of oxygen is injected into the igniter body (which is water-cooled) between the two fuel jets, and high-frequency discharges ignite the propellants forming a pencil of flame penetrating back into the main burning chamber.

In the gas generator, which comprises a water-jacketed inner steel shell, the main liquid oxygen supply is injected tangentially to the igniter flame, forming an oxygen-rich zone in which the main fuel is introduced through three swirl jets. Farther downstream water is injected through the gas generator shell; the temperature of the resultant gas mixture is about 625 deg. C., and the chamber pressure at full thrust is 400 lb. per sq. in.

The combustion chamber has been the subject of extensive development. A plain cylindrical burning zone with a final expansion nozzle, instead of the more efficient convergent-divergent configuration, was found to be the lightest and most compact arrangement, and the loss in performance due to its adoption was insufficient to counteract these other advantages. It also rendered easier the problem of cooling. As a result of trying many schemes for water-cooling, helical flow passages were abandoned in favour of axial flow. In the system used on the Meteor engine the water, after cooling the expansion nozzle, was led to the forward end of the combustion chamber and flowed thence through the rest of the cooling jacket, some being bled into the chamber as internal film cooling through rings of small holes spaced at intervals along the wall. On a later design the water flowed through the jacket from the expansion nozzle end to the backplate and was then all injected axially as film cooling.

Again, a variety of injector patterns have been tried for the main propellants. In the Meteor installation they are introduced into the upstream end of the combustion chamber through plain shower-head injector holes in the backplate, connected by radial passages with concentric fuel (outer) and oxygen (inner) manifolds. For maximum performance, however, Armstrong Siddeley's development engineers would favour the use of impinging pairs of jets of like propellants, i.e., fuel-on-fuel and oxygen-on-oxygen.

The use of water-cooling has, it is estimated, resulted in an inner wall temperature not exceeding 600 deg. C. This has made possible the use of mild steel for both outer and inner shells, the latter being hard-chromium plated to withstand the scrubbing effects of the hot gases; in other parts cadmium plating is used.

The development of propellant pumps and control valves, etc., has presented less of a problem because experience on the earlier " Snarler " liquid-oxygen/methanol rocket engine has provided a substantial starting point. The " Snarler " it may be recalled, was described in the September 17, 1954, issue of ENGINEERING (vol. 178), and the liquid oxygen pump was one of the principal points of interest on this unit. Because of the hazard of oil and oxygen in close proximity, the front journal bearing of the " Snarler " oxygen pump, adjacent to the impeller, was unlubricated. The " Snarler ", however, had only a limited life whereas the " Screamer " was required to withstand at least 25 hours' operation. For this reason, in the " Screamer " pump all bearings had to be lubricated and are therefore sealed off from contact with liquid oxygen.

An open-sided impeller is preceded by a screw-type booster unit. The pump gland is a fluon-bronze face seal on a steel disc bearing on a fixed spring-loaded Hecla ring; a lip-type oil seal prevents oil from the bearings from entering the impeller housing, and as a further precaution a complex labyrinth system is provided to separate any oxygen which may leak past the impeller seal. To prevent heat transfer between the impeller housing and the bearing housing, there is no metal contact between them; they are connected through a Durestos block.

The complete weight of the installation is 450 lb. For a duration of 1 minute at the full thrust of 8,000 lb., a total of 2,400 lb. of propellants would be required in the proportion of 63 per cent. oxygen, 24 per cent. kerosine and 13 per cent. water. The corresponding tankages would be about 135, 75 and 30 gallons.

Performance curves for the " Screamer " are given in Fig. 3. The explanation of the broken line labelled " break-away " is as follows. The expansion nozzle on the Screamer was designed to expand the gases down to ambient pressure at 20,000 ft. when the motor was giving 8,000 lb. thrust. As the engine was throttled at that altitude, the gases were at first over-expanded, but continued to flow as far as the end of the nozzle. When the thrust reached about 2,800 lb. (from the curve) the gases were so far over-expanded that they would not flow as far as the end of the nozzle but broke away from the wall at some point upstream. The thrust at which break-away occurs will vary with altitude. The factor which chiefly decides when break-away will occur is the ratio of pressure at the exit from the expansion nozzle to the ambient pressure.

Over-expansion leads to drag and loss of performance; once break-away has occurred these losses are decreased, so the rate of decrease of specific thrust becomes less—hence the discontinuity in the curves.

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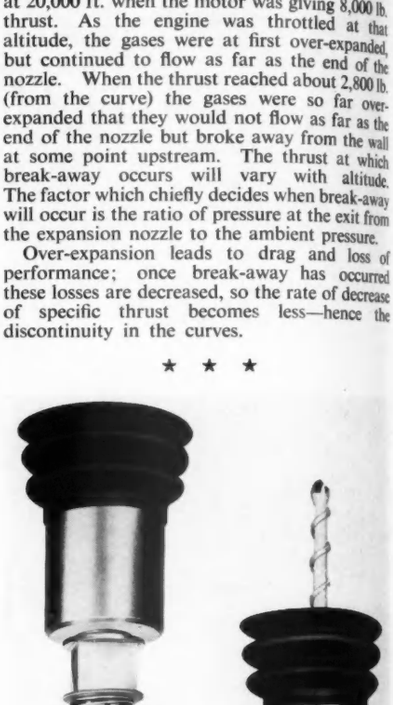


Dust caused by rotary drilling in a mine roof is caught in the bucket surrounding the drill bit. The rubber hood forms a seal with the roof.

DUST COLLECTION FROM FLUTED MINING DRILLS

A simple device for collecting the dust from fluted mining drills, when used in a vertical or diagonal overhead position, has been introduced by the Mine Safety Appliances Company, 201 North Braddock Avenue, Pittsburgh, Pa., U.S.A. Known as the " Drildust Bucket," the device consists of a rubber hood and a collecting bucket with a hanger assembly to slide over the drill.

Dust created by drilling falls by gravity into the bucket, the rubber hood being pressed against the roof to form a dust-tight seal. When the hole is drilled to the required depth the drill is withdrawn in the normal way, and the bucket is removed and emptied. The drill is then drawn back through the hanger until the bit is about level with the bucket lip. Drilling of another hole can then commence. The appearance of the dust collector is shown in the above illustration.

ATOMIC REVIEW

Pattern of Research

Research carried out by one of Britain's four main atomic energy groups in preparing its tenders for the Bradwell and Berkeley nuclear power stations (materials, heat transfer, prototype testing and simulator)—Discussing plans for a second international atomic energy conference—Nuclear power station consultants—Courses in atomic energy—Grant to CERN—Energy loss and range of electrons and positions tabulated—Turbo-jet engine powered by a reactor.

With the approach of October 1, when tenders for the Bradwell and Berkeley nuclear power stations are due to be submitted, there is a natural interest in the work that has gone into preparing them. Recently the G.E.C. Simon-Carves Atomic Energy Group has published details of the research carried out to this end at its laboratories in the Fraser and Chalmers Engineering Works, Erith, Kent. Although this work may not follow exactly the lines taken by the other three groups, it is likely to be broadly typical of a common approach, and gives, therefore, some idea of the basic knowledge required in designing a nuclear power station. Some general remarks on the progress of the G.E.C. Simon-Carves Atomic Energy Group appeared in a Weekly Survey note in last week's issue.

Materials

It has been suggested that a reactor should be designed round the properties of available materials; that materials be regarded as the basic consideration from which all other features follow. The specification of materials required for service within a reactor circuit is governed by three factors not normally encountered in engineering design. First, many of the well-tried materials in common use must be excluded because of their high neutron absorption cross-sections. Secondly, in spite of the most elaborate remote handling devices, there are still many components within the reactor, essential for its operation, which cannot be inspected, maintained or replaced once the reactor has started running. Thirdly, irradiation alters the properties of metals, causes profound changes within the fuel, damages most organic materials to an extent which precludes their use, and alters the fundamental characteristics of many chemical and physical processes. Within these limitations, materials must be found which will have adequate strengths at high temperatures and under high pressures, which can be fabricated into the desired form and in the required quantities, and, above all, which are economically feasible.

The functions of the two materials research laboratories at Erith are to assess the performance of materials for use in the present design of reactor and to carry out research into new and modified materials for future designs. The laboratories are specially and comprehensively equipped to deal with the kind of problems which occur in nuclear power station design.

A major consideration is the corrosion and oxidation of the metals employed. The carbon dioxide coolant gas circulated under pressure through the reactors and heat exchangers will contain small amounts of water vapour and carbon monoxide produced by interaction with the graphite moderator. A considerable amount of experimental work has therefore had to be carried out to determine the oxidation and corrosion resistances to these gases of materials in the reactor circuit.

For corrosion tests on steels and other alloys a battery of 23 G.E.C. vertical heat treatment furnaces has been installed in the two laboratories. Each furnace is fitted with a removable pressure-tight stainless-steel autoclave in which specimens are placed. Tests have been carried out in mixtures of carbon dioxide and carbon monoxide of varying compositions, with and without additions of water vapour, and over a range of gas pressures; temperatures employed range from 300 to 500 deg. C. It appears, however, that the critical factor in high-temperature conditions is not oxidation but creep. Fig. 1 is a general view of one of the G.E.C. Simon-Carves materials laboratories where work of this kind is carried out, while Fig. 2 shows two pressure-tight autoclaves in which experiments on corrosion and oxidation resistance are performed.

Some of the tests for which the autoclaves have recently been used may be listed to indicate the type of work in progress: (1) measuring the creep of canning materials; (2) investigating the oxidation of anodised magnesium alloys in dry carbon dioxide; (3) checking the compatibility of uranium with canning materials; and (4) determining the rate of oxidation in carbon monoxide, carbon dioxide and water vapour at 200 lb. per sq. in. In experiment (4) two sets of conditions were being tried: a temperature of 450 deg. C. and 0·05 per cent. water vapour in one autoclave and 500 deg. C. and 0·10 per cent. water vapour in the other. Another experiment being carried out at the Erith laboratories was a combined stress corrosion and creep test. It was emphasised that it was useless to investigate the results of one condition in the absence of the other. So that the atmosphere in which the test took place could be maintained, direct loading was employed, otherwise a liquid seal would have been necesssry, in which case tests could only have been performed at atmospheric pressure. A battery of stress corrosion machines is being installed. Initially, work will again be on magnesium in carbon dioxide atmospheres, but the equipment can readily be converted for future work to deal with other materials and other corrosive media. Atmospheric corrosion tests on steel are also in progress, as are various investigations at temperatures up to 500 deg. C. on such metals as magnesium, zirconium, beryllium, niobium and "Magnox"—a magnesium alloy with additions to control grain size, weldability and creep resistance. The principal interest so far has been in magnesium alloys used for the fuel element cans and in various steels employed in the construction of the reactor pressure vessels, heat exchanger shells, gas ducting and other components.

Fig. 1 It has been said that a nuclear power station should be designed round the properties of available materials. One of the G.E.C. Simon-Carves materials research laboratories for atomic energy work is shown here.

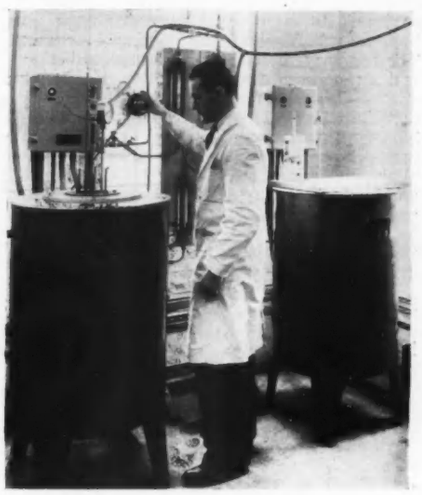


Fig. 2 Experiments on corrosion and oxidation resistance are carried out at the G.E.C. Simon-Carves Atomic Energy Group's laboratories in pressure-tight autoclaves heated electrically.

A special thermo-balance has been designed and constructed for the rapid measurement of magnesium oxidation rates in carbon dioxide. It consists of an electrically heated pressure vessel containing a spiral quartz spring supporting the specimen. The specimen is heated in an atmosphere of carbon dioxide under pressure, and as oxidation takes place weight changes are reflected in the vertical movement of the quartz spring. These movements are observed through a pressure-tight window by a travelling microscope, and the progress of oxidation can thus be followed continuously without the need to dismantle the apparatus and weigh the sample at intervals. By using a number of these vessels simultaneously, operating at different pressures or temperatures, graphs of oxidation with time can quickly be obtained. The apparatus can, of course, be used for metals other than magnesium. One factor considered has been the effect on oxidation of pressure.

The reactor pressure vessels and heat-exchanger shells are both of welded steel construction and the selection of suitable steels requires careful consideration. The pressure vessels will be fabricated on site and the essential requirements of the steel are resistance to creep at the operating temperature, resistance to failure by brittle fracture, and weldability. It is worth noting that the thickness of pressure vessel that can be welded on site is usually regarded as the ultimate limit to coolant gas pressure. Each reactor pressure shell will weigh several hundred tons and will be subjected to a combination of pressure and temperature probably never before attained in a vessel of this size.

The cooling fins on the fuel-element cans are

subjected to bending stresses caused by the high-pressure coolant gas flowing over them. The fins may therefore creep during operation, and a test rig has been devised to examine this effect. Other equipment contributing to the metallurgy research programme are: a G.E.C. 25 kW high-frequency furnace, which can be used for melting small quantities of metals and alloys, including those with high melting points, and for work on powder metallurgy and brazing; and a 300 ampere argon arc welding set to help in the development of suitable techniques for welding magnesium alloys, stainless steel and other materials.

Heat Transfer

In the present design of nuclear reactor, heat is extracted from the natural uranium fuel by carbon dioxide gas circulated under pressure by blowers. The fuel rods are contained within a magnesium-alloy can which must have some form of extended, or finned surface to assist in the extraction of heat. A major item in the research programme has been to determine the optimum extended surface for the fuel elements.

Two views of a pressurised carbon-dioxide rig for experiments on the heat-transfer properties of fuel cans are shown in Fig. 3. Here the measurement of heat-transfer coefficients and friction factors is carried out under conditions of temperature and pressure resembling those in a reactor. The fissile fuel is replaced by a stainless-steel heating element inside the fuel can, the heater power being supplied by two direct-current generators. The can is supported within a copper tube which is lagged to prevent heat losses. Carbon dioxide from "Cardice" generators is circulated under pressure throughout the system by a steam-turbine driven blower; provision is made for supplying the gas with extra heat and also for making-up the small losses of gas that occur during circulation. During tests, measurements are made of gas and fuel-can temperatures, gas flows and pressure drops to obtain a heat balance.

For other experimental work there is also a heat-transfer rig in which experiments are carried out in air at atmospheric pressure instead of pressurised carbon dioxide. This equipment is basically similar to the carbon dioxide rig but is very much simpler and quicker to operate. In this case air is drawn over the cans by a blower which is driven by a constant-speed motor through a fluid drive. The apparatus provides valuable data on the maximum heat output that can be obtained from a given design of fuel can at a particular temperature.

Apart from the problem of extracting heat from the fuel cans, there is the question of heat transfer within the can itself, that is, from the centre of the uranium fuel rod, where the heat is generated, to the outside of the fuel, and also from the surface of the fuel to the walls of the can. The effect of surface roughness on the inside of the can and of oxide films on the uranium are additional factors influencing the effectiveness of heat transfer. These and other problems are being studied.

The hot gas from the reactor passes to steam-raising heat exchangers, and because of the relatively low temperature difference compared with orthodox plant of the same output, considerable attention has been given to achieving a compact arrangement of heat-exchange surface in order to keep the size of pressure vessel required to a minimum. The solution adopted is to use large numbers of small-diameter steel tubes with extended surfaces in the form of fins. Tests have been carried out on studded surfaces and helical and longitudinal fins; economy of manufacture is an important factor in the final choice. The combined heat exchangers for one nuclear power station might contain up to 300 miles of tubing. The use of extended surfaces in such large plant and under such conditions is unusual and has entailed a major development programme.

Equipment constructed for the experimental work is shown in Fig. 4 and in an illustration on page 231 of our last week's issue. In practice the hot gas will pass downwards through the heat exchangers over the banks of tubing through which water and steam are flowing. Heat transfer is therefore inwards through the heat exchanger tubes to the water. In the experimental apparatus this procedure is reversed; that is, dry superheated steam is passed through the heat exchanger tubes and heat is extracted from them by a current of cooling air. An assessment of the effectiveness of a particular design of tube is then easily obtained by measuring the amount of steam condensed in a given time.

Prototype Testing

It is essential that equipment which is of vital importance to the successful operation of the reactor should be thoroughly tested under reactor operating conditions before it is installed. Several prototype units are therefore undergoing tests in the Erith laboratories. These units include sections of the charge and discharge equipment, control-rod operating mechanisms, gas selection valves, special gas seals for carbon dioxide blowers (see Fig. 5), mechanical and electrical drive units operating in hot carbon dioxide, and bearings which will have to be run in hot gas without conventional lubrication. Tests are also being carried out on pneumatic motors, driven from a compressed-air supply, running in a furnace in carbon dioxide under pressure and at temperatures up to 200 deg. C.

One seal that has been examined is known as a viscosity seal. It is employed where a shaft passes through a partition dividing two gases, say the atmosphere and carbon dioxide. Oil is used as the sealing agent but this must not be allowed to escape into the gas spaces. The shaft carries a metal cylinder or bearing which runs in a bush fitted through the partition. The surface of the cylinder embodies two sets of helical grooves which are so arranged that when the cylinder revolves in a particular direction oil on its surface tends to be carried towards its central waist. Oil is thus prevented from passing outside the ends of the cylinder and into the gas circuit.

Another series of tests concerns the danger of fracturing the fuel lattice plates when heavy safety rods are dropped into the reactor. A rig has been built which lifts and lowers a replica safety or control rod into position.

Power Station Simulator

What is said to be the most comprehensive nuclear power station simulator yet built in Great Britain has recently been installed in the Erith laboratories. It was previously mentioned in ENGINEERING on May 18 (vol. 181, page 356, 1956) and is illustrated in Fig. 6. It is an electronic analogue computer which can simulate the kinetic behaviour of a complete nuclear power station. It has been designed and built by Elliott Brothers (London), Limited, Nuclear Division, Century Works, London, S.E.13, to meet the requirements of G.E.C. Simon-Carves for problems associated with gas-cooled graphite-moderated reactor stations, although its flexibility will also allow it to be used for the study of other reactor systems. Initially its main application will be to the study of transient phenomena occurring in a nuclear power station following disturbances such as fault conditions, and to the analysis of automatic control systems. One fault that has recently been investigated, for example, is the failure of power to the gas blowers responsible for circulating the carbon dioxide through the reactor. Other simulated tests can be carried out for separate prototype items of equipment.

The use of an electrical analogue enables the behaviour of a particular unit or group of units in the plant to be predicted accurately and quickly without the need for long and laborious calculations. A simple example would be the variation in reactor power with movement of the reactor control rods. A series of normal calcu-

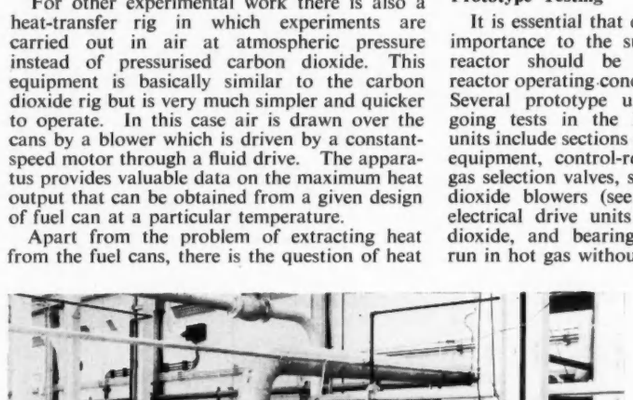


Fig. 3 Pressurised carbon-dioxide rig. A heating element is placed inside the fuel can, carbon dioxide is passed over the exterior and a heat balance obtained. Heat-transfer coefficients and friction factors are measured under reactor operating conditions.

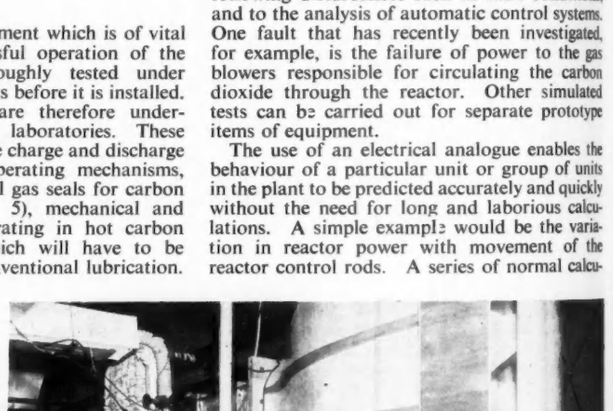


Fig. 4 Small diameter tubes with finned surfaces have been chosen for the heat exchangers in the G.E.C. Simon-Carves nuclear power station design. The apparatus illustrated has been used to investigate the efficiency of different forms of extended surface on the heat-exchanger tubes.

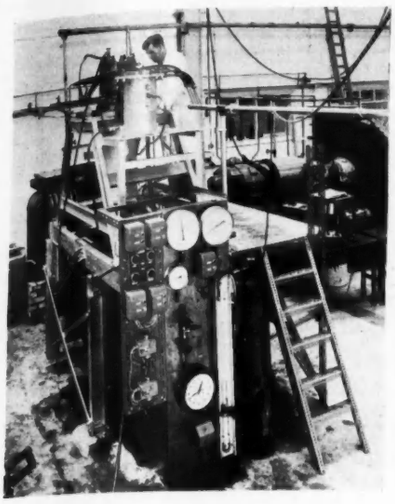


Fig. 5 (left) In preparing their design and tender for the Bradwell and Berkeley nuclear power station, G.E.C. Simon-Carves have tested a variety of prototype equipment. This apparatus is shown testing special gas seals.

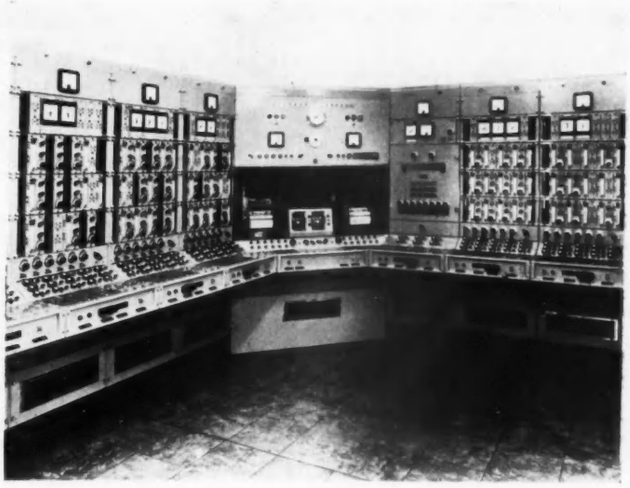


Fig. 6 (right) An analogue computer built by Elliott Brothers (London) Ltd., for simulating the kinetic behaviour of a nuclear power station has been installed in the G.E.C. Simon-Carves Erith laboratories. It can be used for studying transient phenomena arising from fault conditions.

lations taking a considerable time to perform would enable a graph to be drawn showing this variation. By setting the appropriate voltages on one section of the new computer, its electrical circuits can be made to simulate the behaviour of the actual equipment and to record the required graph on a paper chart. More complex problems, involving the interdependence of several sections of the plant, can be dealt with equally well and in these cases the saving of time and effort is even greater.

The new computer is housed in its own room, the air in which is maintained at slightly above atmospheric pressure so as to minimise the ingress of dust. An adjacent workshop is equipped for carrying out routine servicing and testing of computer units, and will also be used for the construction and testing of auxiliary circuits for the machine as these become necessary. The computer comprises a total of 8 cabinets, arranged in an L with the control cabinet at the junction. One special cabinet is permanently connected to simulate the nuclear reactor itself, with controls which can be pre-set to represent different fissile materials, step changes in reactivity, temperature, degree of poisoning and other factors. The remaining six are identical general-purpose cabinets which can be set up to simulate the performance of heat exchangers, control rods, blowers, turbines, alternators or other components of the power station plant.

Provision is made for the incorporation of 100 drift-corrected amplifiers and 20 servo-multiplier units. At present 84 amplifiers are available, any one of which can be used as a summing amplifier, integrator, or servo-amplifier. There are sufficient amplifier units to permit representation of a large number of simultaneous equations. Multiplication is performed by high-speed servo-multipliers operating from the standard amplifier units. A transit time-lag simulator permits the inclusion of the effect of coolant transport from reactor to heat exchanger; this time lag, which can be adjusted from 2 to 60 seconds, is continuously variable and can be controlled from the voltage output from an amplifier unit. Two transit time units are provided for the simulation of time delays; the output signal of each unit is the input signal delayed in time. The computer is so arranged that, if desired, two independent problems may be solved simultaneously. In many of the problems encountered the time scale is likely to range from a fraction of a second to several hours. The computer normally operates in real time and the performance of any section of the power station can be examined from the traces of two continuous high-speed pen recorders which allow four variables to be recorded simultaneously. Alternative indication of each section is provided by a cathode-ray oscillograph. An additional advantage of real-time working is that actual units of a control system can be connected to the simulator and their behaviour analysed. For longer-term problems (such as determining the effects of poisoning in the fuel) the rate of working can be accelerated.

We may now consider some of the components in greater detail. The direct-current amplifier units have a range of -100V to $+100$V and use Bristol's "Syncroverter" choppers. Long-term drift is less than $\pm 100\mu$V and effective grid current is less than 10^{-11}A. The servo-multipliers are plug-in units, operating directly from the computing amplifiers, and will multiply up to 5 quantities. Adjusted for best step response (50 milliseconds rise time, 6 per cent. overshoot), the natural frequency is 13 cycles per second. Adjusted for best frequency response, the natural frequency is 30 cycles per second. Reference power units provide $+100$V and -100V supplies at 0·5A with stability better than 0·1 per cent. Automatic clamping occurs whenever an amplifier output reaches its limit of ± 100V and serves to disconnect all integrator inputs, holding the outputs long enough for voltages to be measured prior to re-scaling.

The reactor kinetics cabinet is permanently wired for 6 reactor kinetics equations with 5 groups of delayed neutrons. Delay constants and delayed neutron fractions are set in by manual controls. This cabinet also includes a graphic problem-patching panel: amplifier and multiplier inputs and outputs are brought to a series of sockets on a patch panel which is engraved to show, in block-diagram form, the function of each socket. Coefficients and initial conditions are set in by means of wire-wound potentiometers. A built-in timer stops a computation after a pre-set time or, alternatively, records the time at which automatic clamping occurs. A time base is embodied, which may be used to operate a standard laboratory oscilloscope for the display or photography of fast transients. Time scales of 10, 1, 0·1 and 0·01 sec. are provided, and there are also camera trigger and brightening pulses.

Notices

The next meetings of the Secretary-General's Advisory Committee on the Peaceful Uses of Atomic Energy are due to begin on September 28 at United Nations headquarters. The principal item on the Committee's agenda is discussion of plans for a second international technical conference like that held last year in Geneva.

C. S. Allott and Son, North-parade, St. Mary's Parsonage, Manchester 3, are working as civil engineering consultants to the atomic energy group comprising the English Electric Company, Limited, Babcock and Wilcox Limited, and Taylor Woodrow Construction Limited. The consultants have recently opened a London office (20 Bedford-row, W.C.1), which is now chiefly concerned with civil engineering work for the Central Electricity Authority's Bradwell and Berkeley nuclear power stations.

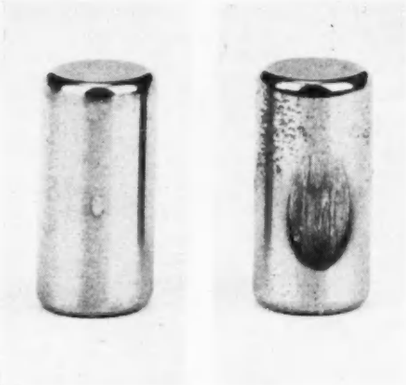
Two courses for engineers wishing to acquire a knowledge of nuclear energy are to be held at the South-East London Technical College, Lewisham-way, London, S.E.4. The first, entitled "An Introduction to Nuclear Physics for Engineers," will comprise six lectures to be held on Tuesday evenings (6.45 to 9.15 p.m.) commencing on October 9, and given by W. P. Jolly, B.Sc. They will require very little mathematics or previous experience of nuclear matters. The second, "Nuclear Power Engineering with Special Reference to Control and Instrumentation," will be generally for students who have attended the first course or others with some knowledge of nuclear physics, and will commence on November 20. Lectures will also be given on Tuesday evenings (6.45 to 8.45 p.m.) and will be delivered by various specialist lecturers. Some topics to be discussed are shielding, reactor kinetics and control, the Calder Hall type of nuclear power station, physical instruments, analogue computers, and reactor operation and maintenance. Inquiries should be sent to the head of the Department of Electrical Engineering and Applied Physics.

The European Organisation for Nuclear Research (CERN) has recently accepted an offer by the Ford Foundation of a grant of 400,000 dols. to be spent over five years, to help in strengthening co-operation in nuclear physics research, primarily with the United States and with other countries not members of CERN. The grant is expected to be used mainly to enable guest professors to to take part in the activities of CERN, and to give young scientists opportunities of working in its laboratories.

A booklet (Circular 577), entitled "Energy Loss and Range of Electrons and Positrons" has recently been published by the United States National Bureau of Standards (U.S. Government Printing Office, Washington 25, D.C. Price 30 cents). It tabulates the mean energy loss due to ionisation and excitation and the range derived from this quantity for electrons and positrons in several materials. Other data on radiation physics published by the Bureau of Standards include Graphs of the Compton Energy-Angle Relationship and the Klein-Nishina Formula from 10 keV to 500 MeV (N.B.S. Circular 542).

Propulsion Postscript

Further to our Atomic Review on "Propulsion" last week (page 252), we learn that last January "a turbo-jet engine was for the first time powered exclusively by heat from an experimental reactor operating on the ground." This announcement was recently made by the chairman of the United States Atomic Energy Commission, Mr. Lewis L. Strauss, speaking before the House Appropriations Committee. The experiment, he said, had been carried out at the A.E.C's testing station in Idaho.



The bearing on the left, tested in a standard oil containing additive, shows only a slight polishing effect, whilst the bearing on the right having passed through the same test using the same standard oil shows considerable wear and also indicates metal deterioration.

ANTI-FRICTION ADDITIVES

Of recent years many compounds have been added to oils and greases for various purposes. A recent one is Dextrol concentrate 905, manufactured by United Lubricants Limited, United House, Cromwell-place, London, S.W.7, which has been developed for its anti-friction properties and showed an excellent performance during tests. The pure compound (it is normally marketed as a 50 per cent. solution in oil) is non-inflammable and also non-toxic; it has a boiling point of 270 deg. C. and freezes at −28 deg. C. which make it suitable for most climatic conditions.

The tests referred to were carried out on a Timken apparatus. This consists of a hardened steel disc about 1¾ in. in diameter, driven by an electric motor. The lower part of the disc dips in an oil bath, in which the oil under test is placed, while a stationary hardened steel roller bears on the upper surface. The bearing force is applied by a calibrated torque wrench and an ammeter shows the corresponding motor consumption. The relative speed of the rubbing surfaces is in the region of 90 ft. per min.

At the demonstration, tests were made on eight commercial oils, ranging from a light spindle to a visco-static and including soluble cutting oils, first as purchased from the suppliers and then with the addition of approximately 10 per cent. of Dextrol concentrate 905. In each case a load of approximately 100 lb. was applied (in two cases it was not possible to reach this figure without seizure) for a period of 20 seconds, and the roller was examined for wear. Then the load was steadily increased until seizure occurred. With all the oils tested as supplied, the wear was severe, in some cases extremely so, and seizure occurred at a load of about 120 lb. The ammeter reading increased from the no-load value of 1·12 amps. to somewhere between 1·8 and 2·0 amps. and the test was accompanied by a loud screeching noise. The best performance was obtained from a sulphurised cutting oil which required a load of about 180 lb. to cause seizure.

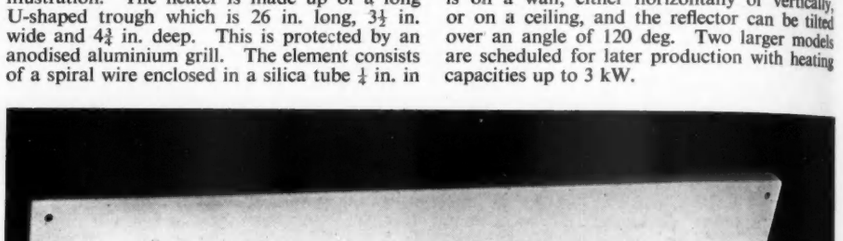
To the same oils, about 10 per cent. of the additive was introduced and the tests repeated. The absence of the friction screech was immediately noticeable and at 100 lb. load the ammeter readings ranged between 1·13 and 1·18 amps. only—very little above the no-load value. After 20 seconds operation, the wear on the roller amounted to little more than polishing in the worst case and was hardly visible in most. In two cases seizure occurred at about 550 lb. load, but for the remainder it was beyond the capacity of the torque wrench, the highest calibration of which was 600 lb.

As a further proof of the uses of the additive, it was added to water (it emulsifies immediately) and again the wear was reduced from severe to a mere polishing. This improvement was not affected when about 10 per cent. of concentrated sulphuric acid was added to the mixture. Again carbon tetrachloride with 10 per cent. additive was also shown to have excellent lubricating properties, and it was not possible to load the bearing to seizure. For the final test a little of the concentrate was squirted over the revolving disc which was then wiped with a duster; the ensuing test, again for 20 seconds at 100 lb., showed that good lubrication still existed, for the ammeter reading was only 1·13 amps. and only polishing occurred. Seizure took place at 525 lb. load.

The additive is miscible with all oils and greases, and readily forms an emulsion with water. It is not affected by acids and alkalis, nor is there any tendency to settle out of solution. It is understood that tests have been carried out by several authorities, including British Railways and Rolls-Royce, and have been entirely satisfactory. Increased cutting speeds and reduced tool wear have been reported from the machine shops and satisfactory lubrication has been obtained in some cases that have hitherto given difficulty. The product is made entirely in this country and the materials do not have to be imported.

ENCLOSED RADIANT HEATER

One of the difficulties of installing electric heaters in bathrooms, kitchens, and other damp atmospheres has always been the danger of electric shock from an exposed element. The type of heater that has now been put on the market by Hanovia, Bath-road, Slough—the Radisil—overcomes this difficulty. The general construction can be seen from the accompanying illustration. The heater is made up of a long U-shaped trough which is 26 in. long, 3½ in. wide and 4¾ in. deep. This is protected by an anodised aluminium grill. The element consists of a spiral wire enclosed in a silica tube ¼ in. in diameter, the connections being at each end of the tube. Three element sizes are available rated at 250 W, 500 W or 750 W. The inner coil of wire can be replaced independently of the silica sleeve. Being totally enclosed the risk of fire through clothes touching the element is greatly reduced, and it is not affected by splashes or steamy atmospheres. The normal mounting is on a wall, either horizontally or vertically, or on a ceiling, and the reflector can be tilted over an angle of 120 deg. Two larger models are scheduled for later production with heating capacities up to 3 kW.



NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
"Electricity in Cable Making," by G. H. Clowes. North London Branch. 677 Green-lanes, Harringay, N.4. Wed., Sept. 5, 7.45 p.m.

CROYDON
Various short lectures by branch members. South London Branch. Half Moon Hotel, Broad Green, Croydon. Thurs., Sept. 6, 8 p.m.

GLASGOW
Film Evening. Glasgow Branch. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Wed., Sept. 5, 8 p.m.

ILFORD
"The Work of the Association of Supervising Electrical Engineers," by H. E. J. Butler. North East London Branch. Angel Hotel, Ilford. Mon., Sept. 3, 7.30 p.m.

LEEDS
"Fire Prevention," by R. French. Leeds Branch. Showrooms of the Electric Lamp Manufacturers' Association, Leeds. Mon., Sept. 3, 7.30 p.m.

LIVERPOOL
Branch chairman's address, by F. T. Bartho. Liverpool Branch. Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool. Fri., Sept. 7, 7.30 p.m.

MANCHESTER
Discussion on "Management in Industry." Manchester Branch. Engineers' Club, Albert-square, Manchester. Wed., Sept. 5, 7.30 p.m.

PRESTON
"Electrical Accessories," by E. Gouch. Preston Branch. R.A.F.A. Club, East View, Preston. Wed., Sept. 5, 7.30 p.m.

SHEFFIELD
Branch chairman's address and open discussion. Sheffield Branch. Royal Victoria Station Hotel, Sheffield. Mon., Sept. 3, 7.30 p.m.

Cornish Engines Preservation Society

CAMBORNE
Annual General Meeting. Holman Museum, Camborne. Sat., Sept. 8, 2 p.m. (Part of an all-day programme beginning with a view of the East Pool engines, from 10 a.m. to 12 noon.)

Incorporated Plant Engineers

LONDON
"Maintenance of Lancashire and Economic Boilers," by J.H. Williams. London Branch. Royal Society of Arts, John Adam-street, Adelphi, W.C.2. Tues., Sept. 4, 7 p.m.*

BIRMINGHAM
Discussion on "Fan Engineering." Birmingham Branch Imperial Hotel, Temple-street, Birmingham. Mon., Sept. 3, 7.30 p.m.

DUNDEE
"Application of Work Study and Incentives to Maintenance," by D. Gardiner. Dundee Branch. Mathers Hotel, Dundee Mon., Sept. 10, 7.30 p.m.

EDINBURGH
Various short discussions opened by members. Edinburgh Branch. 25 Charlotte-square, Edinburgh. Tues., Sept. 4, 7 p.m.

LEICESTER
"Planned Maintenance," by A. F. R. Stedman. Leicester Branch. Bell Hotel, Leicester. Wed., Sept. 5, 6.30 p.m.

Institution of Engineering Designers

NEWCASTLE-UPON-TYNE
Informal discussion on "Design," and branch chairman's address, by A. Jeffrey. North East Branch. Hall of the Northern Architectural Association, 6 Higham-place, Newcastle-upon-Tyne. Mon., Sept. 10, 7.15 p.m.

Television Society

LONDON
"Introduction and Principles of Colorimetry in the (U.S.A. National Television System Committee's System," by P. S. Carnt. First of a series of five lectures. Assembly Hall, Institute of Education, Malet-street, W.C.2. Mon., Sept. 3, 7 p.m. (Fees for course: 10s. to members; £1 for non-members).

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceeding the date of the meeting.

* An asterisk is placed where it is understood that tea is available prior to the time stated.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
Cornish Engines Preservation Society. Apply to Mr. W. T. Hooper, Trevaunance-road, St. Agnes, Cornwall.
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institution of Engineering Designers, 38 Portland-place, London, W.1. (LANgham 8847.)
Television Society, 164 Shaftesbury-avenue, London, W.C.2. TEMple Bar 3330.)

FORTHCOMING EXHIBITIONS AND CONFERENCES

This list, arranged chronologically, appears in the last issue of each month. Events appearing for the first time, and alterations of dates, places, etc., are indicated by an asterisk (*). Particulars of exhibitions and conferences not included below may have appeared in ENGINEERING, *June 29, page 574; or July 27, page 126. Organisers are invited to send to the Editor particulars of coming events as soon as arrangements are made.*

Farnborough Flying Display and Exhibition.—Mon., Sept. 3, to Sun., Sept. 9, at Farnborough, Hampshire. Open to the public on Fri., Sat., and Sun., Sept. 7, 8 and 9, only. Organised by the Society of British Aircraft Constructors, Ltd., 29 King-street, London, S.W.1. Tel. TRAfalgar 3231.

History of Science, Eighth International Congress on, and Fourth General Assembly of the International Union for the History of Science.—Mon., Sept. 3, to Mon., Sept. 10, at Florence and Milan. Apply to Professor Vasco Ronchi, Instituto Nazionale di Ottica, Via San Leonardo 79, Florence, Italy.

Human Relations, Research into Factors Influencing.—Mon., Sept. 3, to Sat., Sept. 15, at Bergen Dal, near Nijmegen, Holland. Apply to the conference secretariat, Raamweg 44, The Hague, Holland.

British Mathematical Colloquium, Eighth.—Tues., Sept. 4, to Thurs., Sept. 6, at St. Andrews. Apply to Mr. D. Borwein, Department of Mathematics, St. Salvator's College, St. Andrews, Scotland.

Fluid Mechanics Symposium.—Wed., Sept. 5, to Fri., Sept. 7, at Göttingen, Germany. Organised by the International Union of Theoretical and Applied Mechanics. Apply to the Union secretary, Professor F. H. van den Dungen, 41 Avenue de l'Arbelète, Boitsfort, Brussels, Belgium.

Applied Mechanics, Ninth International Congress.—Wed., Sept. 5, to Thurs., Sept. 13, at Brussels. Apply to the general secretariat, Université Libre de Bruxelles, 50 Avenue F. D. Roosevelt, Brussels, Belgium.

Radio and Television Exhibition.—Wed., Sept. 5, to Sat., Sept. 15, in Paris. Organised by the Syndicat des Constructeurs d'Appareils Radio Recepteurs et Televiseurs, 23 Rue de Lubeck, Paris, 16e.

***Hydrocarbons Exhibition, First International.**—Thurs., Sept. 6, to Sun., Sept. 16, at Piacenza. Organised by the Chamber of Commerce, Industry and Agriculture, Piacenza, Italy.

***Petroleum Exhibition, International, and Fifth National Methane Exhibition.**—Thurs., Sept. 6, to Sun., Sept. 16, at Piacenza, Italy. Apply to the Italian Chamber of Commerce for Great Britain and the Commonwealth, 652 Grand Buildings, Trafalgar-square, London, W.C.2. Tel. WHItehall 5521.

Handicrafts, Homecrafts and Hobbies Exhibition.—Thurs., Sept. 6, to Fri., Sept. 21, at Olympia, London, W.14. Apply to the exhibition organiser, 24 Store-street, London, W.C.1. Tel. MUSeum 9792.

Cologne International Autumn Fair.—*Household goods and hardware:* Fri., Sept. 7, to Sun., Sept. 9, at Cologne. *Textiles and clothing:* Sun., Sept. 16, to Tues., Sept. 18, at Cologne. *Agent:* Mr. Neven du Mont, 123 Pall Mall, London, S.W.1. Tel. WHItehall 8211.

***Dairy Cattle Fair, International, and 11th National Agricultural Fair.**—Fri., Sept. 7, to Sun., Sept. 16, at Cremona. Agricultural machinery and dairy implements. Organised by the Fiera Internazionale, Palazzo dell'arte, Piazza Marconi 1, Cremona, Italy.

Levant Trade Fair, 20th.—Fri., Sept. 7, to Tues., Sept. 25, at Bari. Apply to the Italian Chamber of Commerce for Great Britain and the Commonwealth, 652 Grand Buildings, Trafalgar-square, London, W.C.2. Tel. WHItehall 5521.

Ghent Fair, 11th International.—Sat., Sept. 8, to Sun., Sept. 23, at Ghent, Belgium. *Agents:* S. R. Tippett & Co., Ltd., 110 Cannon-street, London, E.C.4. (Tel. MANsion House 4500); and Robertson, Buckley & Co., Ltd., Berey's Buildings, George-street, Liverpool (Tel. Central 0952).

***Timber and Wood Industries Exhibition, International.**—Sat., Sept. 8, to Sun., Sept. 23, at*Ghent, Belgium. Part of the Ghent International Fair. *Agent:* Mr. R. C. Liebman, 178 Fleet-street, London, E.C.4. Tel. CITy 5889.

Swiss National Autumn Fair (Comptoir Suisse).—Sat., Sept. 8, to Sun., Sept. 23, at Lausanne. Apply to the commercial secretary, Swiss Legation, 18 Montague-place, Bryanston-square, London, W.1. Tel. PADdington 0701.

German Agricultural Show.—Sun., Sept. 9, to Sun., Sept. 16, at Hanover. Apply to the Deutsche Landwirtschafts-Gesellschaft, Niedenau 48, Frankfurt-on-Main.

Analytical Chemistry Congress (15th International Congress of Pure and Applied Chemistry).—Sun., Sept. 9, to Sun., Sept. 16, at Lisbon, Portugal. Apply to Mr. P. A. Laurent, Istituto Superior Tecnico, Avenida Rovisco Pais, Lisbon, Portugal.

***Vienna Autumn Trade Fair, International.**—Sun., Sept. 9, to Sun., Sept. 16, at Vienna, Austria. Apply to the British-Austrian Chamber of Commerce, 29 Dorset-square, London, N.W.1. Tel. PADdington 7646.

Fatigue of Metals Conference.—Mon., Sept. 10, to Fri., Sept. 14, in London. Organised by the Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. Tel. WHItehall 7476.

Electron Transport in Metals, Symposium on.—Mon., Sept. 10, to Fri., Sept. 14, at Ottawa, Canada. Apply to Professor P. Fleury, International Union of Pure and Applied Physics, 3 Boulevard Pasteur, Paris, 15e.

High Speed Photography, Third International Congress and Exhibition.—Mon., Sept. 10, to Sat., Sept. 15, at Government Offices, Horse Guards-avenue, London, S.W.1. Sponsored by the Department of Scientific and Industrial Research. Apply to the Congress Secretariat, D.S.I.R., Charles House, 5-11 Regent-street, London, S.W.1. Tel. WHItehall 9788. See ENGINEERING, November 11, 1955, page 671.

***Radio and Television Exhibition, 22nd, and Fourth National Exhibition of Domestic Electrical Appliances.**—Mon., Sept. 10, to Wed., Sept. 19, at Milan. Confined to Italian products. Exhibition offices: Via Donizetti 20, Milan, Italy.

Utrecht International Autumn Fair.—Tues., Sept. 11, to Thurs., Sept. 20, at Utrecht. *Agent:* Mr. W. Friedhoff, 10 Gloucester-place, London, W.1. Tel. WELbeck 9971.

***Council of Industrial Design, Congress.**—Wed. and Thurs., Sept. 12 and 13, at the Victoria and Albert Museum and the Royal College of Art, South Kensington, London, S.W.7. Theme: "The Management of Design." Apply to the Council of Industrial Design, 28 Haymarket, London, S.W.1. Tel. TRAfalgar 8000.

Building Plant Exhibition.—Wed., Sept. 12, to Wed., Sept. 19, at the D and E Car Parks, Gosforth Park Racecourse, Great North-road, Newcastle-upon-Tyne. Organised by the Ministry of Works, Lambeth Bridge House, London, S.E.1. Tel. RELiance 7611.

Sussex Industries Exhibition and Trade Fair.—Wed., Sept. 12, to Sat., Sept. 22, at the Corn Exchange, Brighton. Organised by the Federation of Sussex Industries Ltd., 32 Duke-street, Brighton, 1. Tel. Brighton 26189.

Static Electricity in Textiles, Overseas Conference on.—Thurs., Sept. 13, to Mon., Sept. 17, at Zürich. Apply to the general secretary, Textile Institute, 10 Blackfriars-street, Manchester 3.

Fishery Equipment Exhibition, International.—Sat., Sept. 15, to Sat., Sept. 22, at Istanbul, Turkey. Organised by the Government of Turkey to coincide with the fourth meeting of the General Fisheries Council for the Mediterranean, to be held at Istanbul from Sept. 17 to 22. The Council is sponsored by the Food and Agriculture Organisation of the United Nations. Apply to Mr. Cihat Renda, Meat and Fish Office, Selanik Cad. 78, Ankara, Turkey.

Measurements and Instruments, Conference and Exhibition.—Sat., Sept. 15, to Sun., Sept. 23, at Stockholm. Particulars of conference obtainable from Mr. Sven Malström, Box 12035, Stockholm 12; and of exhibition from Anders Beckman Inc., Smalandsgaten 2, Stockholm.

***Instrument and Measurements Exhibition, Fourth International.**—Sat., Sept. 15, to Sun., Sept. 23, at Stockholm. Organised by Anders Beckman Inc., Smalandsgaten 2, Stockholm 0, Sweden.

***German Industrial Exhibition.**—Sat., Sept. 15, to Sun., Sept. 30, in Berlin. *Agent:* Mr. Neven du Mont, 123 Pall Mall, London, S.W.1. Tel. WHItehall 8211.

Marseilles International Fair.—Sat., Sept. 15, to Mon., Oct. 1, at Marseilles. *Agents:* Butlers Advertising Service, 22 St. Giles High-street, London, W.C.2. Tel. TEMple Bar 5905.

Electrochemical Thermodynamics and Kinetics, Eighth Annual Meeting of the International Committee on.—Sun., Sept. 16, to Thurs., Sept. 20, at Madrid. Organised by the Comité International de Thermodynamique et de Cinétique électrochimiques. Apply to the Committee's secretary-general, Dr. M. Pourbaix, 50 Avenue Franklin Roosevelt, Brussels, Belgium.

Functions and Education of Welding Engineers, Conference on.—Mon. and Tues., Sept. 17 and 18, at Ashorne Hill, Leamington Spa. Organised by the Institute of Welding, 2 Buckingham Palace-gardens, London, S.W.1. Tel. SLOane 9851.

Electron Microscopy, European Regional Congress on.—Mon., Sept. 17, to Thurs., Sept. 20, at Stockholm. Apply to Mr. J. Rodin, Karolinska Institutet, Stockholm, Sweden.

British Road Federation's International Conference.—Mon., Sept. 17, to Thurs., Sept. 20, at Friends House, Euston-road, London, N.W.1. Theme: "Urban Motorways." Organised by the British Road Federation, 26 Manchester-square, London, W.1. Tel. WELbeck 0221.

***American Society for Testing Materials.**—*Pacific Coast National Meeting:* Mon., Sept. 17, to Fri., Sept. 21, at the Hotel Statler, Los Angeles, Calif. Offices of the Society: 1916 Race-street, Philadelphia 3, Pa., U.S.A. (Alteration of dates.)

Instrument Automation Conference and Exhibit.—Mon., Sept. 17, to Fri., Sept. 21, in the Coliseum, New York. Organised by the Instrument Society of America, 250 West 57th-street, New York, U.S.A.

International Astronautical Federation, Seventh Annual Congress on.—Mon., Sept. 17, to Sat., Sept. 22, at Rome. Apply to Mr. J. A. Stemmer, International Astronautical Federation, P.O. Box 37, Baden, Germany.

Institute of Metals Autumn Meeting.—Mon., Sept. 17, to Tues., Sept. 25, at Stuttgart and Frankfurt. Organised by the Institute of Metals, 17 Belgrave-square, London, S.W.1. Tel. BELgravia 3291.

Automatic Computing, Cambridge Summer School on.—Mon., Sept. 17, to Fri., Sept. 28, at Cambridge. Apply to Mr. G. F. Hickson, secretary, Board of Extra-Mural Studies, Stuart House, Cambridge.

Association of Public Lighting Engineers, Annual Conference.—Tues., Sept. 18, to Fri., Sept. 21, at Winter Gardens, Blackpool. Exhibition of Street Lighting Apparatus and Equipment at Winter Gardens, and Outdoor Display of Lamp Columns and Mobile Equipment in the Middle Walk Promenade. Organised by the Association of Public Lighting Engineers, 17 Victoria-street, London, S.W.1. Tel. ABBey 4281.

Plastic Theory of Structures, Symposium on.—Tues., Sept. 18, to Fri., Sept. 21, at Clare College, Cambridge. Organised by the Department of Engineering, University of Cambridge, Engineering Laboratory, Trumpington-street, Cambridge. Tel. Cambridge 55691.

***Book Fair, Eighth International.**—Wed., Sept. 19, to Mon., Sept. 24, at Frankfurt. Printing machinery. Organised by the Buchemesse und Ausstellungs-buro des Borsenvereins Deutscher Verleger und Buchhandler Verbande e. V., Grosser Hirschgraben 17–19, Frankfurt, Germany.

***Physical Chemistry of Processes at High Pressures, Conference.**—Thurs. and Fri., Sept. 20 and 21, at The University, Glasgow. Apply to the secretary, Faraday Society, 6 Gray's Inn-square, London, W.C.1. Tel. CHAncery 8101.

Fire Prevention and Extinction, Meeting of the International Technical Committee for.—Thurs., Sept. 20, to Sun., Sept. 30, at Rome. Apply to Dr. Ing. F. Cini, Commandante le Scuole Centrale dei Servizi Anticendi, Capanelle, Rome.

***Technical and Industrial Exhibition, Third International.**—Thurs., Sept. 20, to Mon., Oct. 1, at Charleroi. *Agents:* Weigel, Leygonie and Co., Ltd., 31–32 King-street, London, W.C.2. Tel. TEMple Bar 4825.

Commercial Motor Transport Exhibition, International.—Fri., Sept. 21 to Sat., Sept. 29, at Earl's Court, London, S.W.5. Organised by the Society of Motor Manufacturers and Traders, Ltd., 148 Piccadilly, London, W.1. Tel. GROsvenor 4040.

***Innsbruck Export and Sample Fair.**—Sat., Sept. 22, to Sun., Sept. 30, at Innsbruck, Austria. Apply to the British-Austrian Chamber of Commerce, 29 Dorset-square, London, N.W.1. Tel. PADdington 7476.

Science of Photography, International Conference on.—Mon., Sept. 24, to Thurs., Sept. 27, at Cologne. Apply to Dr. Walter Schürmeyer, Deutsche Gesellschaft für Photographie e.v., Hohenstaufenring 48/54, Cologne, Germany.

Association of Iron and Steel Engineers, Convention and Exhibition.—Tues., Sept. 25, to Fri., Sept. 28, at Cleveland. Apply to the exhibition manager, Association of Iron and Steel Engineers, Empire Building, Pittsburg 22, Pa., U.S.A.

Automatic Controls, Conference on.—Tues., Sept. 25, to Fri., Sept. 28, at Heidelberg, Germany. Apply to the secretary-general, V.D.I./V.D.E. Fachgruppe Regelungstechnik, Haus 35, Hertzstrasse 16, Karlsruhe, Germany.

Business Efficiency Exhibition.—Tues., Sept. 25, to Fri., Sept. 28, at St. Mary's Drill Hall, Southampton. Organised by the Office Appliance and Business Equipment Trades Association, 11-13 Dowgate-hill, Cannon-street, London, E.C.4. Tel. CENtral 7771.

Direction of Research Establishments, International Symposium on.—Wed., Sept. 26, to Fri., Sept. 28, at the National Physical Laboratory, Teddington, Middlesex. Organised by the N.P.L. Apply to Mr. E. S. Hiscocks, secretary, National Physical Laboratory, Teddington. See ENGINEERING, July 13, page 39.

***Materials Handling Convention.**—Thurs., Sept. 27, to Sat., Sept. 29, at Leamington Spa, Warwickshire. Organised by the Institution of Production Engineers, 10 Chesterfield-street, London, W.1. Tel. GROsvenor 5254.

***Nautical Exhibition, International.**—Fri., Sept. 28, to Sun., Oct. 14, in Paris. *Agents:* Auger and Turner Group, 40 Gerrard-street, London. W.1. Tel. GERrard 6671.

***"Photokina" International Photo and Cinema Exhibition.**—Sat., Sept. 29, to Sun., Oct. 7, at Cologne. *Agent:* Mr. Neven du Mont, 123 Pall Mall, London, S.W.1. Tel. WHItehall 8211.

Brussels Colonial Exhibition.—Sat., Sept. 29, to Sun., Oct. 14, in Brussels. Apply to Foire Coloniale de Bruxelles, 20-21 Boulevard Baudouin, Brussels.

Agricultural Engineering Exhibition, Eighth International.—Sat., Sept. 29, to Sun., Oct. 14, at Turin. Connected with the Sixth International Technical Exhibition in this city, being held on the same dates. Apply to the exhibitions secretary, Via Massena, Turin, Italy.

***Technical Exhibition of Cinematography, International.**—Sat., Sept. 29, to Sun., Oct. 14, at Turin. Connected with the Sixth International Technical Exhibition in this city, being held on the same dates. Apply to the exhibitions secretary, Via Massena, Turin, Italy.

***Radio and Television Exhibition.**—Sat., Sept. 29, to Sun., Oct. 14, at the Palais du Centenaire, Brussels. Exhibition offices: 100 Boulevard Louis Schmidt, Brussels.

Metz International Fair.—Sat., Sept. 29, to Mon., Oct. 15, at Metz. *Agents:* Auger and Turner Group, Ltd., Autur House, 40 Gerrard-street, London, W.1. Tel. GERrard 6671.

Chemical Engineering, Tenth Meeting of European Federation of.—Mon., Oct. 1, to Wed., Oct. 3, at Hamburg. Organised by the European Federation of Chemical Engineering, Frankfurt-am-Main, West Germany.

Atomic Energy Course for Management.—Mon., Oct. 1, to Fri., Oct. 5, at the Biltmore Hotel, New York. Organised by the National Industrial Conference Board, 460 Park-avenue, New York, 22.

National Hardware Show.—Mon., Oct. 1, to Fri., Oct. 5, in the Coliseum, New York. Organised by the National Hardware Show, Inc., 331 Madison-avenue, New York.

Traffic Engineering, International Study Week on.—Mon., Oct. 1, to Sat., Oct. 6, at Stresa. Held with the co-operation of the International Road Federation and various Italian organisations. Particulars available from the World Touring and Automobile Organisation, 32 Chesham-place, London, S.W.1. Tel. SLOane 0386.

Weights and Measures, Meeting of International Committee on.—Mon., Oct. 1, to Wed., Oct. 10, at Paris. Organised by the Bureau International des Poids et Mesures, Pavilion de Breteuil, Sèvres (Seine et Oise), France.

***Chemical Research Laboratory, Open Days.**—Tues., Oct. 2, to Thurs., Oct. 4, at the Laboratory, Teddington, Middlesex. Firms already on Laboratory's mailing list need not re-apply. Write to the Director, Chemical Research Laboratory, Teddington, Middlesex.

Fuel Efficiency Exhibition.—Tues., Oct. 2, to Wed., Oct. 10, at Olympia, London, W.14. Organised by Provincial Exhibitions Ltd., in association with F. W. Bridges and Sons, Ltd. Apply to the public relations officer, 9 Southampton-place, London, W.C.1. Tel. CHAncery 2131.

Standards Engineers Society, Fifth Annual Meeting.—Wed., Oct. 3, to Fri., Oct. 5, at the Hotel Willard, Washington, D.C. Theme: "Standards as Guides for To-morrow." Apply to the Society, P.O. Box 281, Camden 1, N.J., U.S.A.

***Zaragoza National Fair, 16th.**—Wed., Oct. 3, to Sun., Oct. 21, at Zaragoza. Organised by the Feria Oficial y Nacional de Muestras, Zaragoza, Spain.

Motor and Cycle Show.—Thurs., Oct. 4, to Sun., Oct. 14, in Paris. *Representative:* R. C. Liebman, 178 Fleet-street, London, E.C.4. Tel. CITy 5889.

***Food Equipment Industries Exhibition.**—Fri., Oct. 5, to Mon., Oct. 15, in Paris. Organised by the Salon de l'Equipement des Industries et des Commerces de l'Alimentation, 42 Rue de Louvre, Paris 1er.

Cattle and Agricultural Machinery Exhibition, National.—Sat., Oct. 6, to Sat. Oct. 13, at the Quinta Normal, Santiago. Organised by the Sociedad Nacional de Agricultura, Tenderini 187, Santiago, Chile.

Chemists' Trade Fair, International (INDROFA).—Sun., Oct. 7, to Sun., Oct. 14, at Düsseldorf. Organised by the Nordwestdeutsche Ausstellungs-Gesellschaft m.b.H. (NOWEA), Ehrenhof 4, Düsseldorf, Germany. *Agents:* John E. Buck and Co., 47 Brewer-street, London, W.1. Tel. GERrard 7576.

"Safe at Work," Exhibition.—Mon., Oct. 8, to Wed., Oct. 10, at the Sophia Gardens Pavilion, Cardiff. Organised by the Cardiff and District Industrial Safety Committee of the Royal Society for the Prevention of Accidents. Offices of the Society: 52 Grosvenor-gardens, Westminster, London, S.W.1. Tel. SLOane 2246.

Metal Exposition, 38th National.—Mon., Oct. 8, to Fri., Oct. 12, at Cleveland, Ohio. Organised by the Metal Show, Department, American Society for Metals, Cleveland 3, Ohio.

Firato Radio and Television Exhibition.—Mon., Oct. 8, to Mon., Oct. 15, in the R.A.I. Building, Amsterdam. Apply to Mr. H. J. Kazemier, Emmalaan 20, Amsterdam-Z.

***Incorporated Sales Managers' Association, Conference.**—Tues., Oct. 9, at the Royal Festival Hall, London, S.E.1. Theme: "The Management Challenge of 1957: Can We Sell Our Way Out of Inflation?" Organised in collaboration with the British Institute of Management, 8 Hill-street, London, W.1. Tel. GROsvenor 6000.

"Vochema" International Fair.—Tues., Oct. 9, to Wed., Oct. 17, at Utrecht. Comprises machinery and equipment for the food industry, and the chemical and pharmaceutical industry. *Agent:* W. Friedhoff, 10 Gloucester-place, London, W.1. Tel. WELbeck 9971.

THE HUMAN ELEMENT

Short-time and unemployment benefit—The printing unions—Negotiating machinery for local Government employees—Maintenance men and production men in the steel industry—Transport and engineering unions prepare for wage application—The state and doctors' earnings.

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Ludicrous Legalities

The right of workers on short-time to unemployment benefit has now been once admitted and once refuted. The second decision does not invalidate the first—both are held to be a correct interpretation of the law and both hinge on technicalities. Whether or not the first ruling will apply, or the second, appears to depend entirely on the wording of the contract between the company and their workers or between employers and trade unions. The long and short of it is this: if a worker is employed on terms which guarantee employment on four or less consecutive days—at whatever time rate of wages—and if the guaranteed-week agreement makes it clear that for the fifth and sixth day the company have no claim on the worker's time, then he is entitled to unemployment benefit for those days. If on the other hand the guaranteed-week agreement specifies a number of hours or merely a guaranteed weekly payment, the implication is that the company have a claim for the worker's time on the fifth day and the worker is therefore not entitled to unemployment benefit.

This is an absurd situation. The unemployment fund was never intended to serve as a subsidy for under-employment. It can be argued, of course, that it is better for the country and less expensive for the fund—and therefore for the taxpayer—to have under-employment than unemployment. But this seems counter to the Government's basic economic policy, which is designed to promote the mobility of labour from certain "home consumption" industries to the "export" industries. Unemployment pay to workers on short-time is an incentive for them to remain where they are and await sunny days. Concerted search is now likely by the employers and the unions for law-worthy contracts which will ensure the payment of unemployment benefit.

More will certainly be heard on this subject. Until the law has been brought up to date into something sensible and realistic, firms will certainly be found to hang on to labour at the taxpayers' expense.

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Rivalry in the Printing House

As the printing industry is settling down to a long period of industrial peace, there are signs of sharpening conflicts between the printing unions concerning the shape of things to come after April, 1959.

The constituent members of the Printing and Kindred Trades Federation have over two years in which to work out a co-operative negotiating procedure that will eliminate the "leap-frogging" of wage claims which has disrupted the industry in recent years. Both courts of inquiry on stoppages (1950 and 1956) recommended negotiations in two-tiers—craft and non-craft. Mr. Robert Willis's attempt to get this implemented at the P.K.T.F. annual conference in May failed, and the conference decided upon a single meeting to "devise a basic wages structure for the industry" in order to repair the serious "lack of unity within its ranks." The first discussion is due next month.

The main obstacle to two-tier negotiations is that no union will admit to being wholly non-craft. NATSOPA, who are likely to join forces with the paper workers in a few months, are disappointed at the lack of response from other unions who have been approached to join a new colossus—the National Union of Printing and Allied Trades Workers. The London Typographical Society and the Typographical Association are themselves discussing a merger, which could develop into a rival organisation. To cap it all, Mr. Briginshaw, of NATSOPA, is to oppose Mr. Willis, of L.T.S., for the printing and paper unions' seat on the T.U.C. So far, therefore, there is more rivalry than unity behind the scenes in the printing world.

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Simplifying Bargaining Procedures

Whereas in British industry collective bargaining procedures tend to be over-centralised and—as in the case of the steel maintenance workers—to cater inadequately for the needs of specialised groups of employees, the reverse is true of local government. There are at present 22 national joint negotiating bodies, several of which are subdivided, covering about 1½ million employees. To some extent this is inevitable because of the wide range of occupations concerned, which include doctors and architects, busmen and dustmen, engineers and teachers, lavatory attendants and road sweepers, etc. There are some 1,500 local authorities divided into six different associations and over 20 trade unions or associations of employees.

A serious attempt is now being made to improve and simplify the negotiating machine. The local authorities' associations have been considering since 1953 how the Local Authorities Conditions of Service Advisory Board can be extended to represent all joint bodies; they have recommended that the National Joint Council for Local Authorities Administrative, Professional, Technical and Clerical Services (the A.P.T. Council) should be extended to include all officers of local authorities except the most senior grades. Likewise that the Manual Workers Council should be expanded to include the Council for County Council roadmen. As Mr. Bryn Roberts, the general secretary of the National Union of Public Employees, pointed out recently "We have two national joint councils determining the wages of county roadmen and making agreements involving different amounts and payable from different dates." Some unions are resisting the proposed changes, and the rivalry between the National Union of Public Employees and the two large general unions does not help matters. Nor are the local authorities always as co-operative as they could be.

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Steel Inquiry Verdict

Craftsmen in the iron and steel industry have every reason to be satisfied with the tone and the contents of the report of the court of inquiry on the dispute which led to a ban on overtime and the threat of a strike. The court recommend that new arbitration machinery should be set up and that the craft unions should consider submitting a claim for a new wage structure. Meanwhile they should accept the wage increase of 10*s.* a week offered to them last March, without prejudice to future claims.

The blame for the dispute is fairly evenly divided: the employers' response to the unions' proposal for amending their national agreement—to avoid arbitration by people who did not fully understand the special and technical problems of the industry, and to avoid hindrances to national negotiations by small local disputes—was in the court's opinion "rigid and intransigent" until too late. The unions on the other hand acted "in a precipitate and unconstitutional manner" in resorting to an embargo on overtime in defiance of their obligations under district agreements for arbitration. The court consider that the use of emergency maintenance teams to safeguard production was fully justified.

The court of inquiry's recommendations should, if accepted, help to remove the main source of conflict between the 12,000 maintenance men and the rest of the industry, which includes production workers as well as employers. The first step is to set up a separate arbitration tribunal. Detailed proposals will presumably follow for a revision of the industry's wage structure to achieve the craft union's main objective, defined by the court as "the reduction of the gap between the earnings of comparable skilled craftsmen and skilled production workers."

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Joint Claims and Joint Consultation

The National Union of Railwaymen announced last week that they had invited the Transport and Salaried Staffs Association and the Confederation of Shipbuilding and Engineering Unions to an early meeting to consider a joint application for a wage increase. It is unlikely that the claim will have been presented before the British Transport Commission gave their reply to the Associated Society of Locomotive Engineers and Firemen on August 29 on their claim for a 15 per cent. increase for their 70,000 members. Its almost certain rejection will doubtless draw together the four unions concerned in the ensuing struggle.

Meanwhile the B.T.C. continue to give evidence of their good intentions in respect of staff and workers. A handbook entitled "Making Joint Consultation Work," has been widely distributed to salaried staff grades and another is to follow for the workshop grades. The new procedure outlined in the handbook reviews the improved machinery for joint consultation at local departmental committee level, which includes a right of appeal to headquarters if views or suggestions are not satisfactorily considered locally. This excellent little leaflet is signed on behalf of the B.T.C. and the unions, and should make a positive contribution to management-labour relations. All this and more will be required if a serious conflict is to be avoided.

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Unfair to Doctors?

The medical profession is fighting a strong rear-guard action to maintain its differentials with other professions, and to bring up the purchasing power of doctors' earnings. In a recent letter to *The Times*, an irate medical practitioner said: "the ordinary doctor is working harder, longer and for less pay than he was four years ago, and he does not like it."

The profession's case for a substantial increase in income (Human Element, August 3, "The Doctors' Pay Claim") is based on two major contentions. The first, and the most basic, is that when the Health Service was being planned two separate committees, both sharing the same chairman (Sir Will Spens), made recommendations on doctors' and specialists' incomes in terms of 1939 money values with the proviso that their figures must be scaled up to contemporary levels by "direct regard not only to estimates of the change in the value of money but to the increases which have in fact taken place since 1939 in incomes in other professions." The Government of the day accepted the recommendations of the Spens committees. The doctors' leaders now say that these were their terms for entering the Health Service and that any repudiation of the Government's pledge must lead them to reconsider their position. The second contention is that the Health Service has resulted in a considerable increase in the health consciousness of the nation and therefore in the work of doctors.

The Government are determinedly adhering to their rejection of the doctors' claims, and by implication failing to honour their predecessors' pledge. The reality of the situation is that it is unrealistic in this age of levelling down for any profession to attempt to maintain its real income at pre-war levels.